DRAFT

Limiting Factor Analyses & Recommended Studies for

Fall-run Chinook Salmon

and

Rainbow Trout

in the Tuolumne River

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by

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Abstract

Historically, annual Tuolumne River adult fall-run Chinook salmon spawning escapement has ranged from pre-New Don Pedro Federal Energy Regulatory Project No. 2299 levels of 40,000 plus to less than one hundred during the six year drought in the late 1980's and early 1990's. This large escapement fluctuation led Tuolumne River resource managers to initiate large scale restoration actions in the mid-1990's including both spawning habitat restoration and elevated minimum instream flow levels. Recently (fall 2005) spawning escapement abundance of adult fall-run Chinook salmon in the Tuolumne River returned to levels below 1,000 fish. Resource managers had hoped restoration efforts would prevent the large scale escapement fluctuation and especially the "bottoming-out" of the salmon population. In addition to the status of salmon in the Tuolumne River, rainbow trout management, especially recovery of the anadromous form steelhead, are also a high management priority.

This paper describes a Tuolumne River Management Conceptual Model (Model) that includes a limiting factor analysis of fall-run Chinook salmon and rainbow trout in the Tuolumne River, unanswered management questions, and recommended management actions that include monitoring studies and experimental instream flow schedules. The primary objectives of the Model are to (a) guide management actions towards accomplishing recovery of fall-run Chinook salmon (*Oncorhynchus tschawycha,)*, resident rainbow trout (*O. mykiss*), and Central Valley steelhead (*O. mykiss)* in the Tuolumne River below La Grange Dam; b) provide reasonable water supply equity across competitive beneficial uses, and c) provide a technical framework enabling collaborative resource management.

Recent trend analyzes suggest that the Chinook salmon population has not responded to recent management efforts to restore spawning habitats and reduce the abundance of exotic fish predators in the Tuolumne River or to reduced export rates in the Delta between mid-April and mid-May. Other factors, such as ocean productivity and ocean harvest also do not explain the trends in the Tuolumne River population. Instead, the analyses indicate that management should focus on providing instream flows of greater magnitude, duration, and frequency during both the winter and spring to enhance the survival of juvenile salmonids in the Tuolumne River and improve the survival of out-migrating smolts in the Tuolumne River and Delta.

Management questions that should be considered include studies to refine the winter and spring flow level magnitude, duration, variation, and frequency needed to accomplish adult Chinook salmon recruitment targets as well as determine how summer minimum flows influence the amount of suitable rearing habitat for rainbow trout. Management actions needed to evaluate these and other management questions include (a) implementation of revised instream flow schedules to better protect, and boost production of, both salmon and rainbow trout, and (b) conducting targeted studies to refine the flow levels and habitat restoration needed to help recover Chinook salmon and rainbow trout populations in the Tuolumne River.

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Introduction

Purpose

The paper describes a Tuolumne River Management Conceptual Model (Model) that includes limiting factor analyses of fall-run Chinook salmon (*Oncorhynchus tschawycha,)*, rainbow trout (*O. mykiss*), and Central Valley steelhead (*O. mykiss*) in the Tuolumne River, unanswered management questions, and recommended management actions that include monitoring studies and experimental flow schedules. This paper is intended to be a living document that, in the spirit of adaptive resource management, is updated as new information regarding management action effectiveness becomes clear. The Agencies[1] that have initiated this Model intend that others will provide information to update this conceptual model over time and will participate in its development and implementation.

Background

The Tuolumne River is located in California's southern Central Valley (Figure 1). The Tuolumne is the largest of the three primary San Joaquin River (SJR) salmonid bearing streams, having a watershed area of 1,540 square miles and an unimpaired mean monthly flow of 1,456 cubic feet per second (cfs). The combined reservoir storage volume for Tuolumne River dams is 2,777,000 acre-feet (AF) [2].

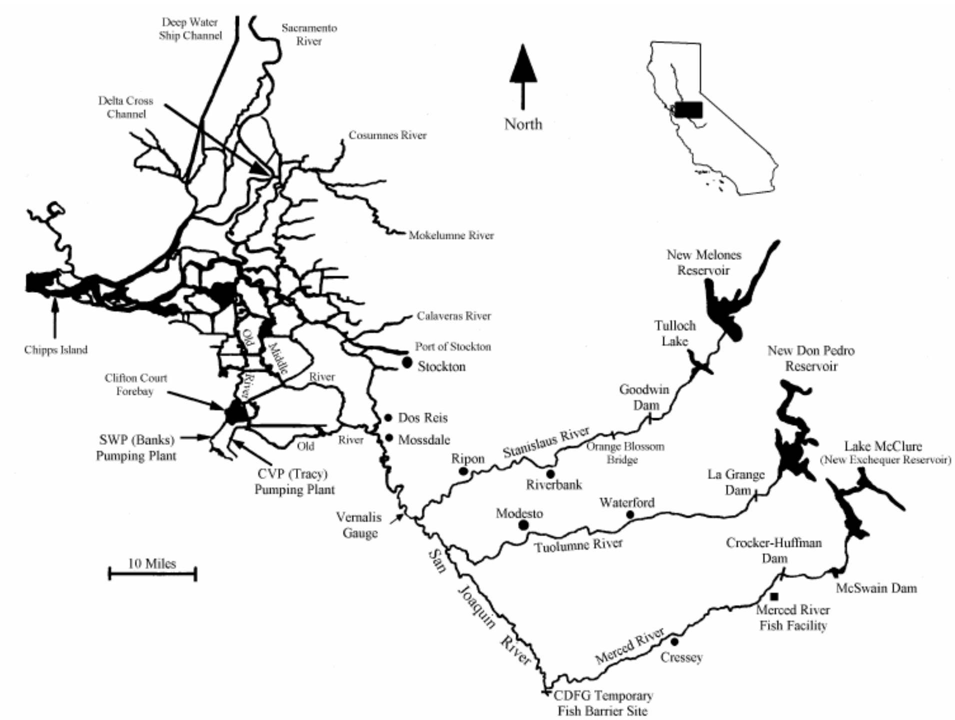

Figure 1. Map of the Stanislaus, Tuolumne, Merced and San Joaquin rivers and the Sacramento-San Joaquin Delta.

[1] California Department of Fish and Game; U.S. Fish and Wildlife Service; National Marine Fisheries Service

[2] Information obtained from USFWS-AFRP website: http://www.delta.dfg.ca.gov/afrp/ws_stats.asp?code=TUOLR

Salmon

There is a self-sustaining, native population of fall-run Chinook salmon (salmon) in the Tuolumne River. Population abundance trends for salmon in the Tuolumne River have dropped substantially in recent history. The average adult salmon production[3] declined from a mean of 18,996 from 1967 to 1991 to a mean of 10,324 from 1992 to 2004 (approximately a 46% decline). Many restoration actions have been identified, and implemented, to increase Tuolumne River adult salmon production. These include (a) increasing minimum instream flows, (b) restoring spawning and rearing habitats, (c) reducing south Delta Exports, and (d) reducing ocean harvest. To date over 40 million dollars[4] has been invested in physical habitat restoration alone in the Tuolumne River. Despite these management actions, the Tuolumne River salmon population continues to decline. Therefore, it is timely to update the foundational framework guiding Tuolumne River salmon restoration is needed.

Trout

The Tuolumne River provides habitat for and sustains populations of rainbow trout (trout) and presumably Central Valley steelhead as well. Steelhead, which is the migratory form of rainbow trout, is thought to occur in the Tuolumne River. Both adult and juvenile steelhead have been documented in neighboring SJR tributaries to the north and south (e.g. Stanislaus and Merced Rivers respectively) and large rainbow trout resembling steelhead have been caught by sport anglers in the Tuolumne River. Juvenile trout have been captured with rotary screw traps and beach seines and adult trout have been caught by anglers primarily in the area between La Grange Dam and Roberts Ferry Bridge. The migratory form of rainbow trout, steelhead, is thought to occur in the Tuolumne River based on photo documentation and anecdotal information however, the presence of steelhead has not been confirmed genetically to date. The National Marine Fisheries Service (NMFS) considers steelhead to be present in a river if the river has both a resident rainbow trout population and has continuity with the ocean. The Tuolumne River meets both of these requirements.

The status of the rainbow trout population in the Tuolumne River is of concern to the Agencies. Effective management of the population in the lower Tuolumne River has been hampered by a lack of basic population data. For example, there are little or no data on the percentages of steelhead and rainbow trout in the population, their abundance and distribution in the river, or the effects of flow on their populations. In particular, steelhead, which are the anadromous form of *O. mykiss*, are protected under the Endangered Species Act and have different habitat requirements than rainbow trout, which is the resident form of *O. mykiss.* Therefore, the Agencies recommend that basic population studies should be conducted for migratory and resident rainbow trout in the lower Tuolumne River.

[3] Includes both ocean harvest and inland escapement
[4] From CVPIA-AFRP Web-site 8/2006.

NMFS listed the Central Valley steelhead Distinct Population Segment (DPS) as threatened on January 5, 2006. The listing includes all naturally-produced Central Valley steelhead in the Sacramento and San Joaquin basins. Central Valley steelhead are widely distributed throughout their range but low in abundance, particularly in the San Joaquin Basin and declines in abundance of Central Valley steelhead are continuing to occur (National Marine Fisheries Service 2003). The low productivity of Central Valley steelhead resulting from the loss of a vast majority of historic spawning areas in the Central Valley and a lack of sufficient knowledge about steelhead are areas of concern. The Agencies regard the anadromous life-history form as a critical component of the diversity of the DPS and are very concerned by the reduced expression of the anadromous life-history form as a result of the many impassable dams. Impassable dams also reduce the abundance and prevent the exchange of migrants among resident populations.

Limiting Factor Analyses

Fall-run Chinook Salmon

The historical abundance of Tuolumne River salmon, as indicated by annual adult salmon escapement abundance estimates (Figure 2), has fluctuated greatly over time. The factors that are associated with the fluctuating trend are of considerable importance to Tuolumne River natural resource managers. When evaluating correlations between the salmon production (dependent variable) and various environmental factors (independent variables), such as flow, stock density dependent mortality, Delta export rates, ocean harvest, etc., it is necessary to segregate annual escapement estimates into age cohorts of same aged fish that were exposed to the same environmental conditions as juveniles. For example, escapement consists of Age 2 through Age 5 fish that belong to different cohorts that were affected by different rearing conditions in the Tuolumne River. The methods used to deconvolve annual escapement estimates and the resulting brood year production values used for the analyzes contained herein are described in Mesick et.al. 2006..

Salmon Abundance and Flow

The intent of the 1996 FERC Settlement Agreement[5] (FSA) and subsequent modified FERC License No. 2299 (License) Articles 37 and 58 was to improve minimum flow levels from the New Don Pedro Project, implement an adaptive management research program, and restore critical habitat to help recover the fall-run Chinook salmon population in the Tuolumne River. However, the number of adult Tuolumne River fall-run Chinook salmon produced at a given spring flow has declined since the FSA was implemented (Figure 3).

[5] The FERC Settlement Agreement, or FSA as its commonly called, is not an official FERC Settlement Agreement but rather is an agreement between entered into in 1996 by the Modesto and Turlock Irrigation Districts, U.S. Fish and Wildlife Service, and the California Department of Fish and Game that proposed flow, and non-flows, actions to improve production of fall-run Chinook salmon in the Tuolumne River.

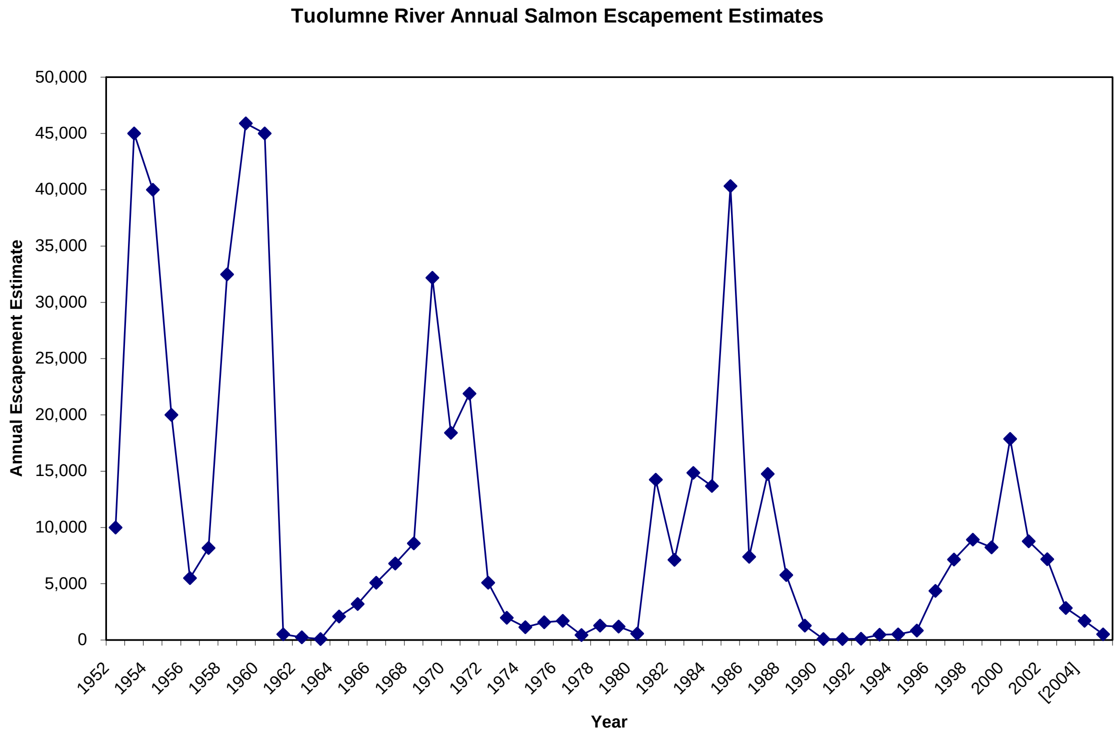

Figure 2. Tuolumne Fall-run Chinook Salmon Annual Escapement Estimates.

Prior trend analysis suggests that the numbers of adult salmon produced in the lower Tuolumne River is strongly correlated with spring time flow (e.g. April and May) when the fish migrated to the ocean as juveniles (as summarized in Mesick and Marston 2006). The most recent evaluation by Mesick and Marston (2006) indicates that spring flows in the San Joaquin River near Vernalis between February 1 and June 15 explain about 96% of the variation in adult recruitment to the Tuolumne River between 1980 and 2003 (Figure 4). Instream flow releases in the Tuolumne River as gauged at La Grange are almost as important as they explain about 87% of the variation in Tuolumne River recruitment. Other factors, such as *Microcystis* blooms, pyrethroid insecticides, water quality in the Stockton Deep-Water Ship Channel, CVP and SWP Delta export rates, Delta Cross Channel Gate operations, and ocean productivity (e.g., upwelling and Pacific Interdecadal Oscillation) have also been tested and have insignificant correlation (r-square) values strongly suggesting that these factors explain relatively little variation in adult recruitment to the Tuolumne, Stanislaus, and Merced rivers (Mesick and Marston 2006).

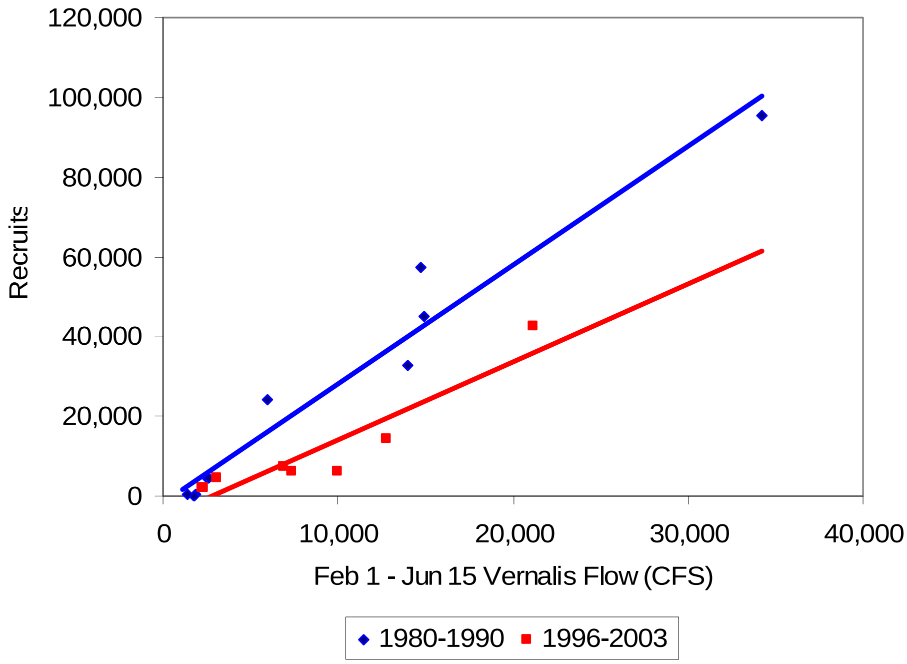

Figure 3. Tuolumne River fall-run Chinook salmon recruitment plotted with mean flow in the San Joaquin River at Vernalis during February 1 through June 15 during two periods: 1980 to 1990 (pre-FSA) and from 1996 to 2003 (post-FSA). Recruitment is the number of adults in the escapement and ocean harvest (including shaker mortality) that belong to individual cohorts of same-aged fish (Mesick et.al. 2006). Estimates were excluded for which spawner abundance was less than 500 Age 3 equivalent fish to minimize the effect of spawner abundance on the relationship between flow and recruitment. Two-tailed *F*-tests indicate that the slope of the linear regression for the Post-FSA period is significantly lower ($P = 0.032$) than for the Pre-FSA period. The variances of the regressions were not significantly different ($P = 0.262$), which is a statistical requirement for comparing regression slopes and elevations

It is likely that spring flow affects juvenile survival in both the Tuolumne River as well as the Delta based on rotary screw trap surveys in the Tuolumne and Stanislaus rivers and coded-wire-tag smolt survival studies in the Tuolumne River and Delta[6]. Preliminary data from rotary screw trap studies conducted in the Tuolumne River near Grayson (RM 5.2) suggest that spring flow releases at La Grange from February 1 to June 15 are highly correlated (adj-$R^2 = 0.93$, $P = 0.001$) with the number of Tuolumne River smolt outmigrants passing the Grayson traps at rivermile 5 (Figure 5)[7], and the number of Tuolumne River smolt outmigrants is highly correlated (adj-$R^2 = 0.89$, $P = 0.003$) with the number of Tuolumne River adult recruits (Figure 6).

[6] It is important to note that Tuolumne River flow level at Modesto is highly correlated with Delta flows at Vernalis (Marston 2005). Relationships between the survival of smolt-sized juveniles and flow are statistically significant at both locations. Therefore, elevated Tuolumne River out-flow improves juvenile salmon survival both in the Tuolumne River and in the South Delta.

[7] The estimates of the number of smolt outmigrants are preliminary because the trap efficiency models have not been finalized and the catch data have not been verified (CDFG unpublished data).

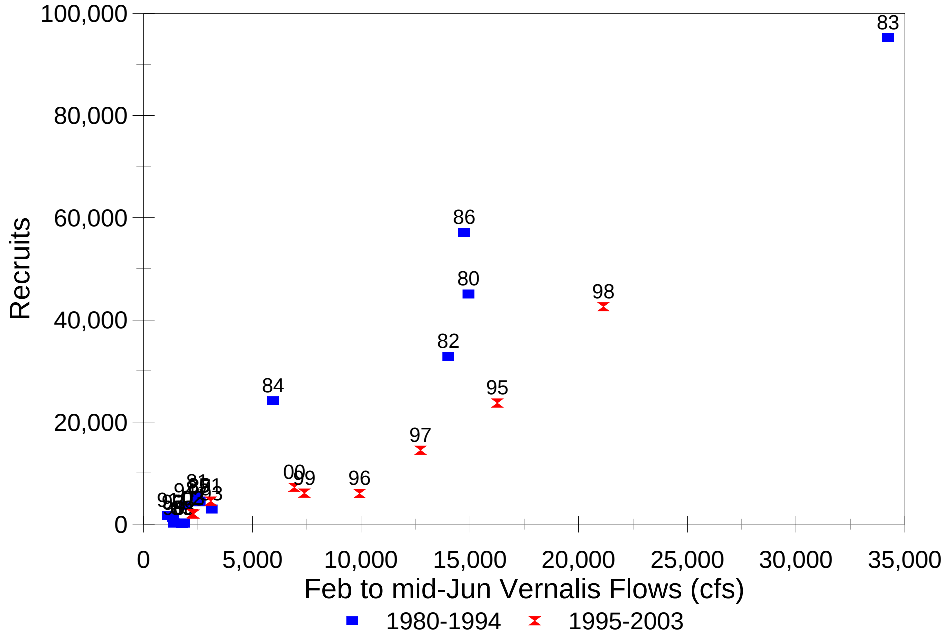

Figure 4. Number fall-run Chinook salmon recruits to the Tuolumne River plotted with flows in the San Joaquin River at Vernalis from February 1 to June 15 from 1980 to 2003. This analysis excludes recruitment estimates that were affected by a low number of spawners (< 500 Age 3 equivalent fish) to better illustrate the relationship with flow. The recruitment estimates correspond to the year when the fish outmigrated as smolts.

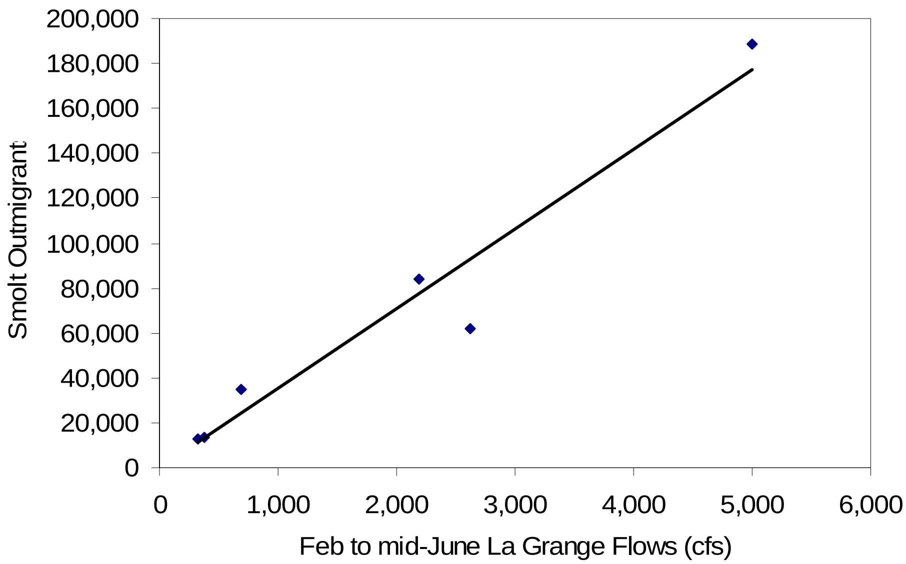

Figure 5. The Number of smolt-sized Chinook salmon outmigrants (FL $\geq$ 70 mm) passing the Grayson rotary screw trap site (RM 5) plotted with flows at La Grange between February 1 and June 15 in the Tuolumne River from 1998 to 2003.

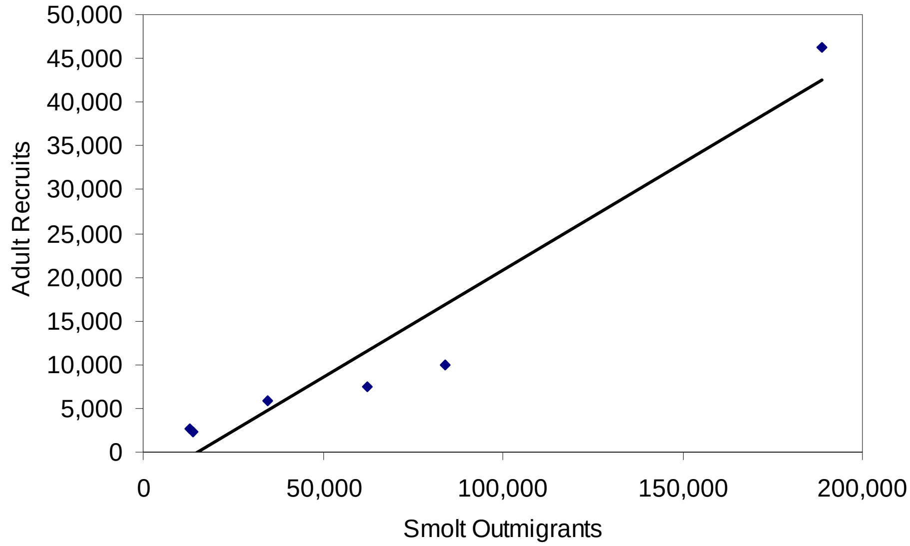

Figure 6. The number of smolt-sized Chinook salmon outmigrants (FL $\geq$ 70 mm) measured at the Grayson rotary screw trap site (RM 5) regressed with the number of adult recruits in the Tuolumne River from 1998 to 2003.

Winter Flow

Historically (pre-FERC Project #2299) spring flow (April and May) in the Tuolumne River was considerably greater in volume than with the pre- or post-Project FSA time periods. Since escapement was considerably greater during this time period, the inclination is to assume that greatly reduced flow post-Project is the primary production limiting factor in light of the demonstrated lack of other cause and affect variables, such as spawning habitat quality or quantity, Delta pumping, Ocean Conditions, and/or Ocean Harvest, to explain the decline (Mesick and Marston 2006). However, winter flows appear to act in unison with spring flows to influence smolt production, thence adult recruitment, in the Tuolumne River.

One indicator of the importance of early flows, between February and early April, to the production of smolt-sized juveniles, is the comparison of comparing the survival of juveniles migrating between the lower end of the spawning grounds and the terminal end of the river. Ideally monitoring results directly from the Tuolumne River would be used to guide restoration actions on the Tuolumne River. However, in the absence of long term monitoring data from the Tuolumne River, data from the Stanislaus River, which also has fall-run Chinook salmon and similar hydrologic conditions, will be used to identify in-river factors that may limit salmon production. During 1998, 1999, and 2000 when flows were high between February and June, juvenile survival averaged 84% (range 74% to 95%) and there were more smolt-sized fish at Caswell than at Oakdale in April and early May, which suggests that juveniles were successfully rearing in the lower river; the spring 2000 data are shown in Figure 7. However, during 2001 to 2003 when flows were pulsed primarily between mid-April and mid-May, juvenile survival averaged 10% (range 7% to 11%) and there was no evidence of successful rearing in the lower river; the spring 2001 data are shown in Figure 8.

Rotary screw trapping studies on the Tuolumne River from 1995 to 2005 were primarily focused on determining the number of smolt outmigrants passing from the river as surveyed at the Shiloh (RM 3.4) and Grayson sites (RM 5.2) and so it is not possible to compare the relationship between February and March flows on the relative passage between an upper and lower screw traps as was done with the Stanislaus River data. However, screw trap surveys were conducted between January and late May at Grayson between 1998 and 2002 that show the same pattern observed at the Caswell State Park trap site in the Stanislaus River: fry, parr, and smolt passage was high during wet years such as 2000 when there were extended periods of high flows in February and March (Figure 9), moderate during dry years such as 2001 when there moderate periods of high flows in February and March (Figure 10), and low during dry years such as 2002 when only base flows were released between February and early April (Figure 11).

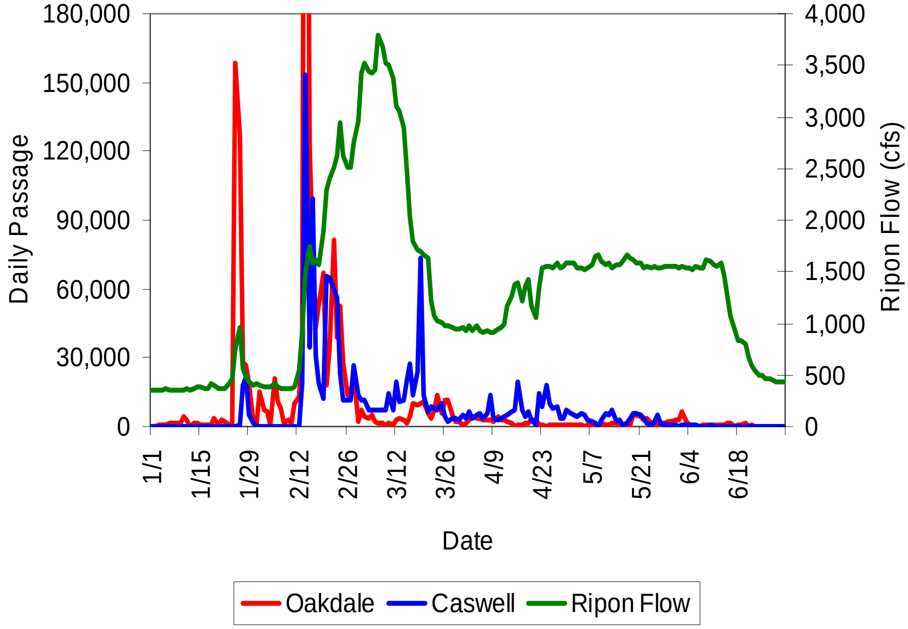

Figure 7. The estimated daily passage at the Oakdale and Caswell Park screw traps plotted with the mean daily flow at Ripon in the Stanislaus River during spring 2000, an Above Normal year. Overall juvenile survival between the Oakdale and Caswell traps was 74% in 2000.

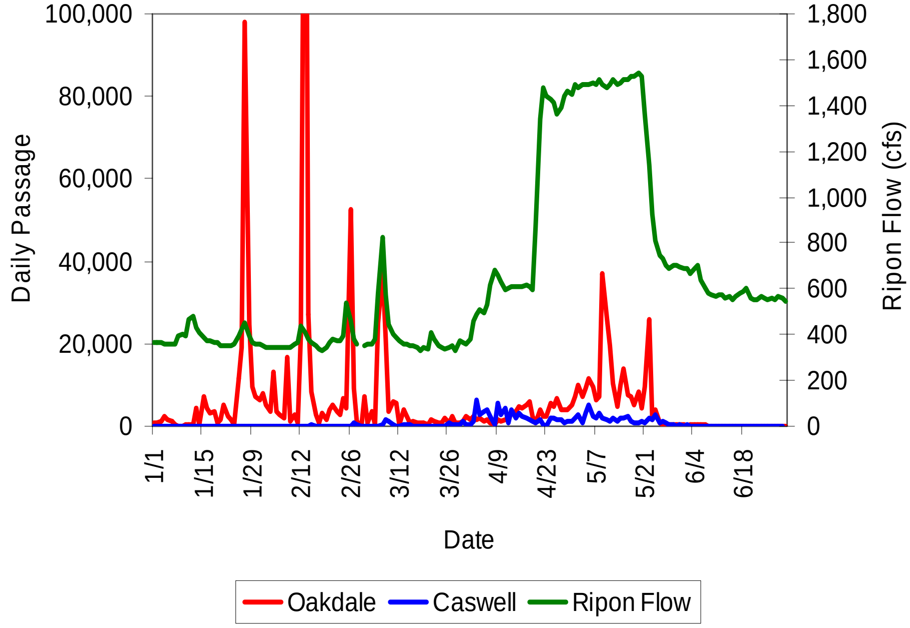

Figure 8. The estimated daily passage at the Oakdale and Caswell Park screw traps plotted with the mean daily flow at Ripon in the Stanislaus River during spring 2001, a Dry year. Overall juvenile survival between the Oakdale and Caswell traps was 11% in 2001.

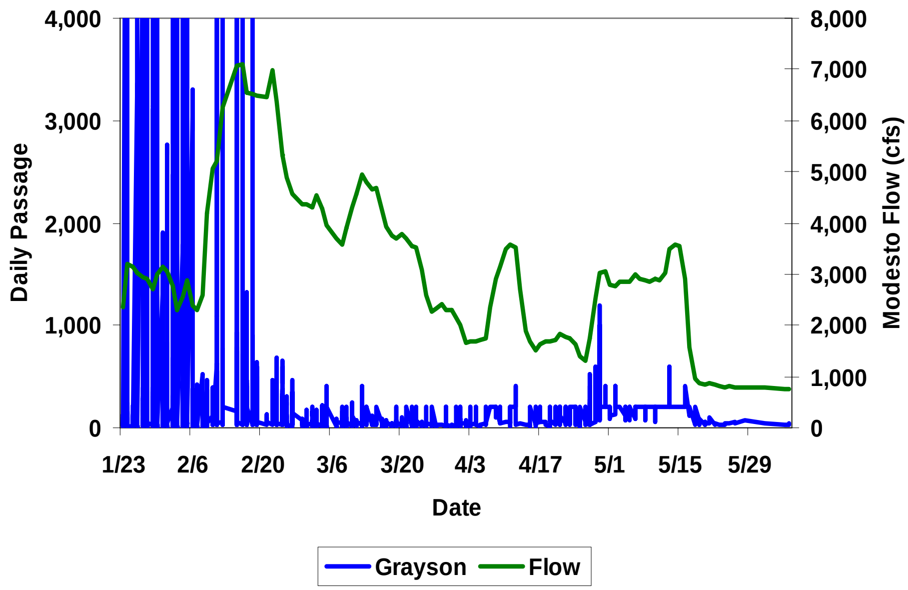

Figure 9. The estimated daily passage (truncated at 6,000 fish/day) at the Grayson screw trap plotted with the mean daily flow at Modesto in the Tuolumne River during spring 1999, an Above Normal year. The total number of all sizes of juvenile out-migrants and smolt-sized (> 70 mm Fork Length) out-migrants was 455,079 and 62,168, respectively.

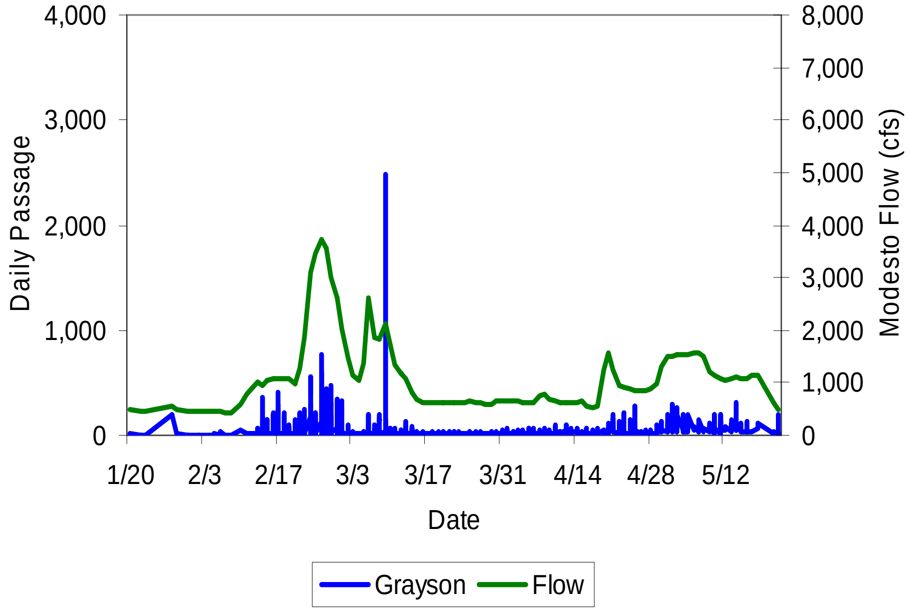

Figure 10. The estimated daily passage at the Grayson screw trap plotted with the mean daily flow at Modesto in the Tuolumne River during spring 2001, a Dry year. The total number of all sizes of juvenile out-migrants and smolt-sized (> 70 mm Fork Length) out-migrants was 111,254 and 34,824, respectively.

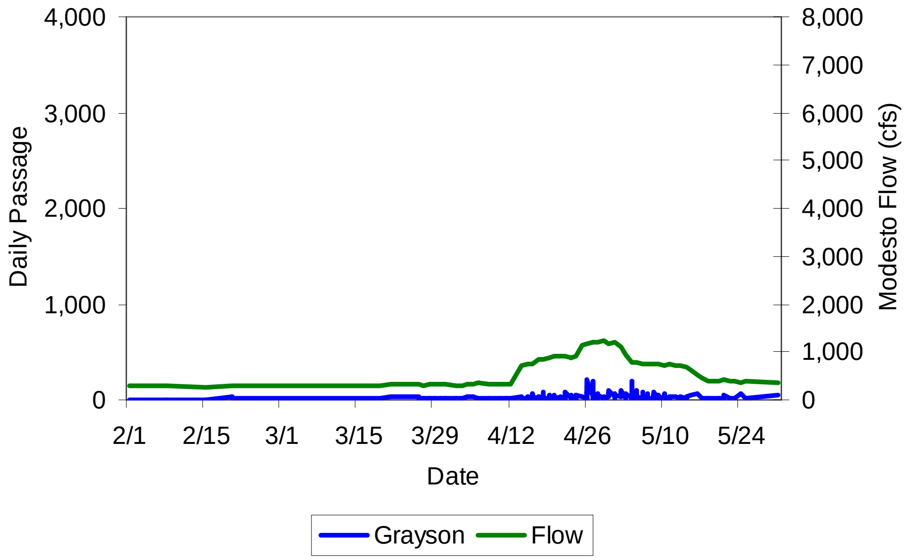

Figure 11. The estimated daily passage at the Grayson screw trap plotted with the mean daily flow at Modesto in the Tuolumne River during spring 2002, a Dry year. The total number of all sizes of juvenile out-migrants and smolt-sized (> 70 mm Fork Length) out-migrants was 13,442 and 13,076, respectively.

Correlation analyses using historical data cannot fully distinguish between the effects of winter and spring flow due to the problem of multicollinearity between the spring and winter flow variables: when spring flows were high, winter flows were typically high as well. So although correlation analyses indicate that spring flow alone explains the greatest overall percentage of variation for each single factor evaluated (adjusted R-Square = 0.72, p = 0.05) and that adding winter flow with spring flow improves the correlation only slightly (adjusted R-Square = 0.77, p = 0.05), the problem with multicollinearity may obscure the true importance of winter flows. A comparison of arithmetic and harmonic means, and the natural logs of each (Table 1) show the difficulty involved in the analysis and the need to experimentally control different combinations of winter and spring flows to demonstrate the relative importance of each.

Table 1. Comparison of regression correlations using different flow metrics against adult recruitment. It interesting to note that fall flow is weakly correlated with adult recruitment, which suggests that fall flow levels may have an affect on adult recruitment.

Table 1. Tuolumne River Flow Time Period Regression Comparison.

Flow Period Regression Comparison Table (1970 thru 2002)								
Dependent Variable	Adj. R-Square	Sig.	Natural Log (avg)	Sig.	Harmonic Mean	Sig.	Natural Log (HM)	Sig.
Fall Flow	0.22	p = 0.5	0.22	p = 0.5	0.17	P = 0.5	0.05	ns
Winter Flow	0.32	p = 0.5	0.65	p = 0.5	0.55	P = 0.5	0.65	P = 0.5
Spring Flow	0.72	p = 0.5	0.58	p = 0.5	0.74	P = 0.5	0.44	P = 0.5

Notes:
1. All regressions use adult recruitment as the independent variable
2. Fall/Winter/Spring flow periods are 10/1-12/31, 1/1-3/14, and 3/15-6/15 respectively.
3. HM = Harmonic Mean

Rather than evaluating means for various time periods, comparing winter flow to spring flow ratios relative to adult recruitment or smolt production may be more informative. For example, Figure 12 shows the relationship between the flow ratios and smolt production in the Stanislaus River. The highest smolt production occurred at a winter to spring ratio of 1.5 and slightly higher smolt production estimates at a winter to spring flow ratio of 4 compared to ratios of about 0.5. This strongly suggests that winter flows may be more important than spring flows in regard to smolt production and presumably adult recruitment.

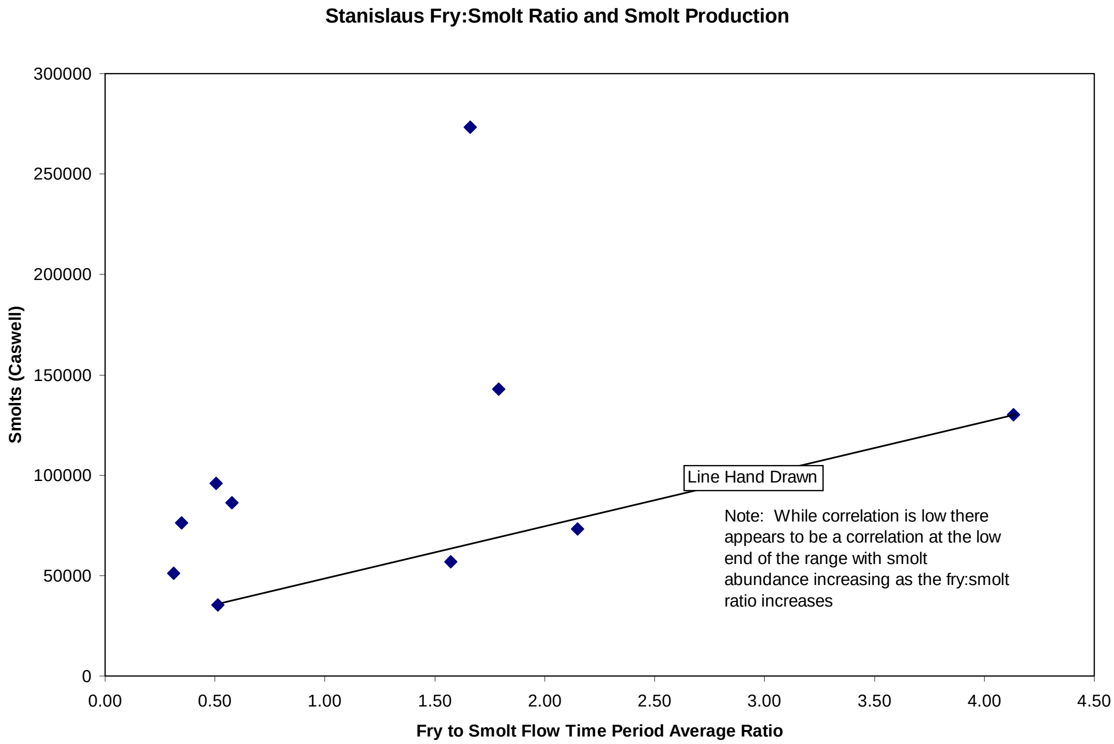

Figure 12. Stanislaus Fry to Smolt Flow Ratio and Smolt Production. Note: Based upon Caswell smolt abundance (>70mm)

The importance of winter flows relative to spring flow can also be shown with adult recruitment in the Tuolumne River by looking at individual annual hydrographs and resulting adult recruitment. In Figure 13 (WY 1992-3) low winter flow occurred with elevated spring flow, which produced an approximate 66% exceedence level of adult recruits. In Figure 14 (WY 1983-4) moderately elevated winter flow occurred with low spring flow, which produced an approximate 22% exceedence level of adult recruits. In Figure 15 (WY 1988-9) low fry flow and low smolt flow occurred, which produced an approximate 97% exceedence level of adult recruits. In Figure 16 (WY 1997-8) both high fry and smolt flow occurred, which produced an approximate 9% exceedence level of adult recruits.

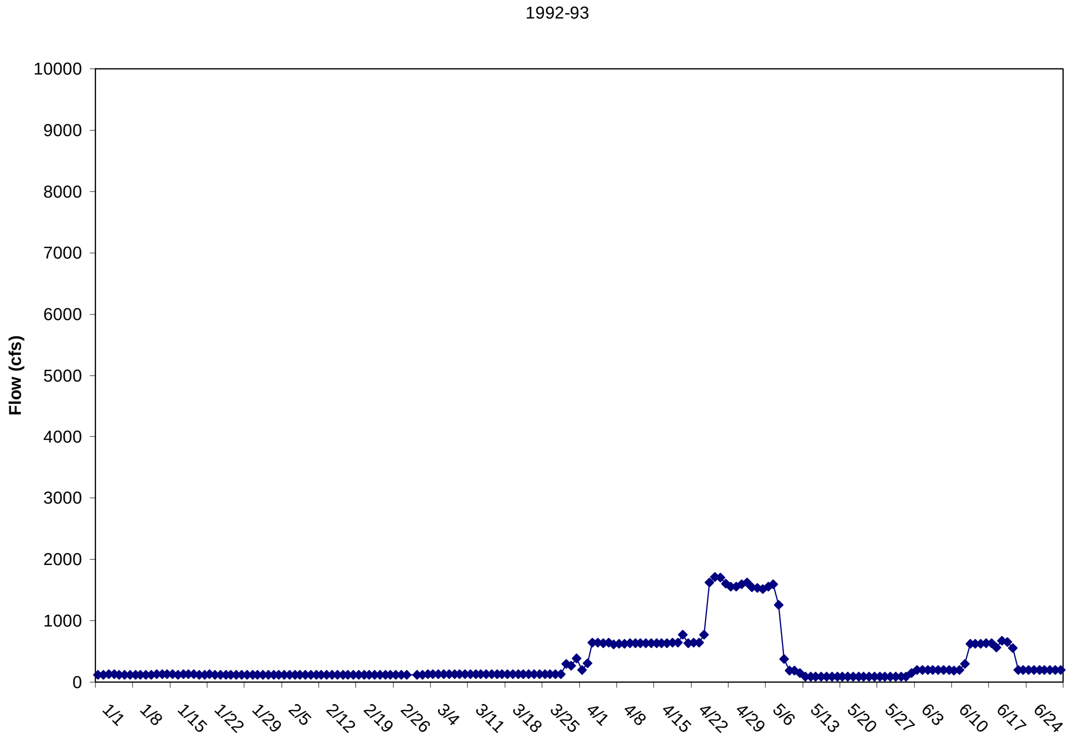

Figure 13. Water Year 1992-93 Winter and Spring Hydrograph (La Grange Flow).

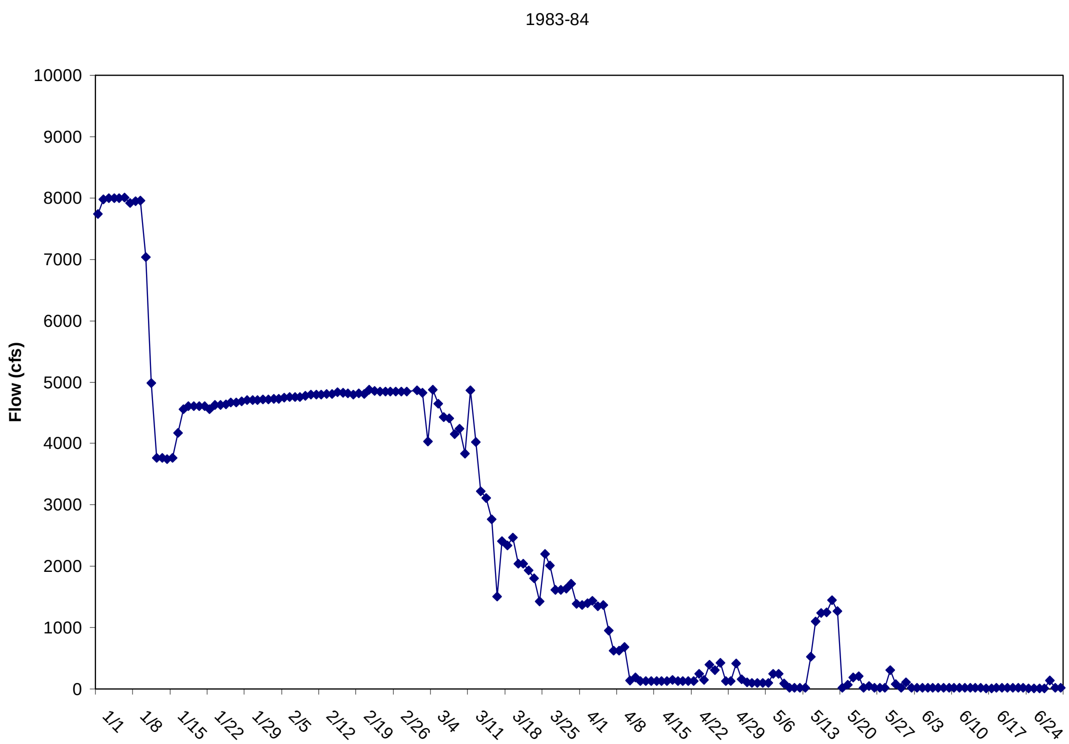

Figure 14. Water Year 1983-84 Winter and Spring Hydrograph (La Grange Flow).

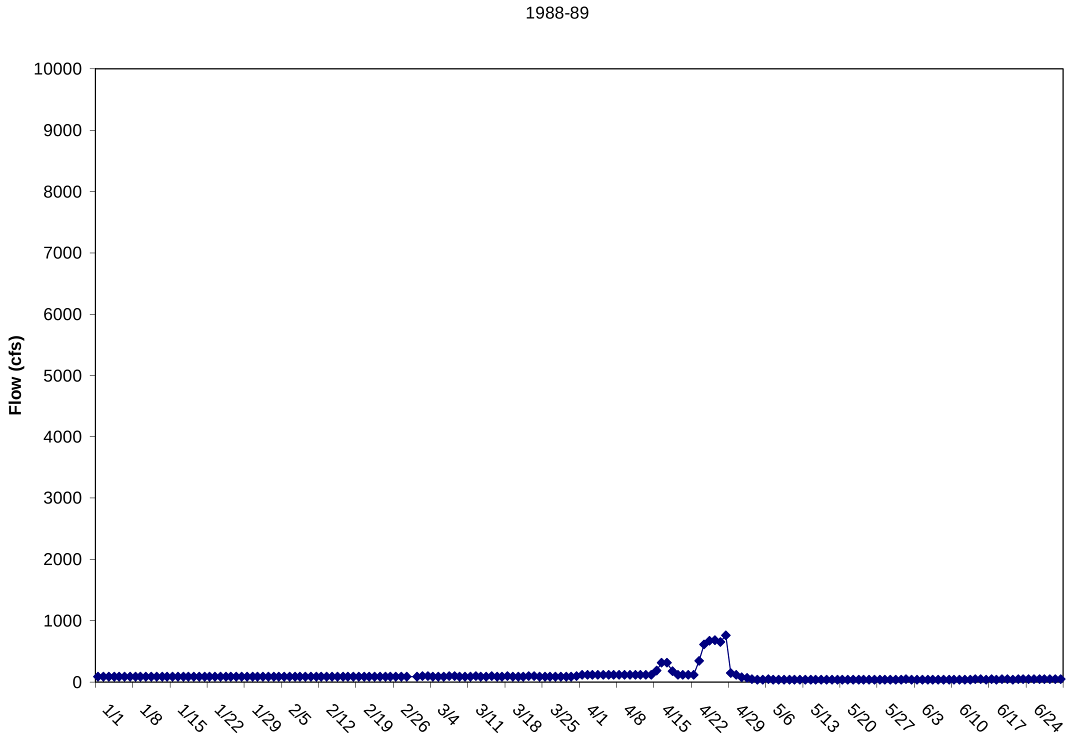

Figure 15. Water Year 1988-89 Winter and Spring Hydrograph (La Grange Flow).

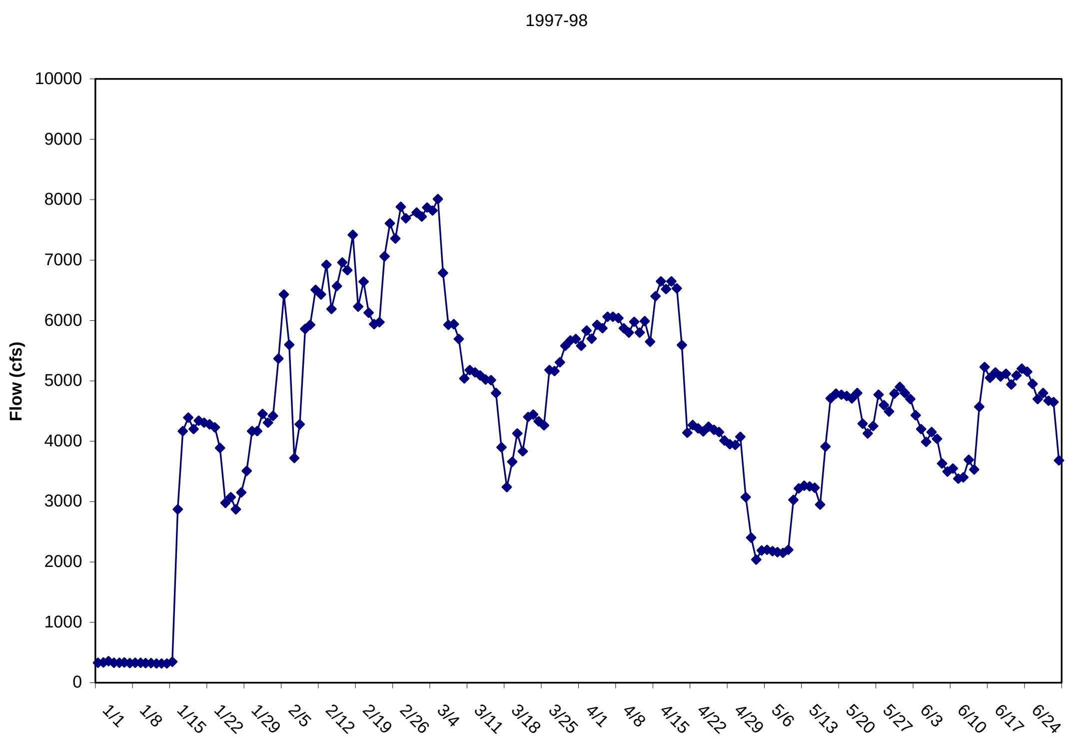

Figure 16. Water Year 1995-96 Winter and Spring Hydrograph (La Grange Flow).

Delta Flow
The Vernalis Adaptive Management Plan[8] (VAMP) coded-wire-tag (CWT) studies conducted with fish reared at the Merced River Hatchery suggest that the survival of smolts migrating in the San Joaquin Delta between Mossdale and Jersey Point increases from an average of 7% when San Joaquin River flows at Vernalis are about 2,500 cfs to an average survival of 14.5% when Vernalis flows are increased to 5,000 cfs (SJRGA 2005)[9]. The CWT studies also indicate that smolt survival is more strongly correlated with San Joaquin River flows at Vernalis, which ranged between 2,500 cfs and 6,500 cfs, than with Delta exports, which ranged between 1,450 and 2,350 cfs during the VAMP study period (SJRGA 2005).

Fall Flow
Fall flows are thought to be a critically important production component for both salmon and steelhead. For salmon, adult migration thru the South Delta and into the Tuolumne River occurs during the early fall when Delta conditions are their worst in terms of water quality and flow. In the early fall dissolved oxygen conditions are typically less than 5 parts per million in the Deep Water Ship Channel and the Delta Pumping to South Delta inflow ratio is typically ten to one or greater making it difficult for adult Tuolumne River salmon to detect their natal waters, and migrate through, the South Delta.

Hallock and others (1970) have shown that flow-related conditions in the deep-water ship channel, which include low dissolved oxygen concentrations (< 5 ppm) and high water temperatures (> 70^{o} F), can block adult migration and it is possible that delaying migrating adults in water that is at least 70^{o} F would reduce the viability of their eggs. Egg viability tends to be lower for the early arriving fish at the Merced River Hatchery, particularly when flows were low and water temperatures were high in the late 1980s and early 1990s prior to the release of October pulse flows, and it is likely that the same is true for Tuolumne River fish (CDFG unpublished data).

Current trend analyzes between fall attraction flows, and fall base spawning flows, have shown little correlation with adult recruitment. Pre-spawning mortality data is not currently collected as part of annual Tuolumne River adult salmon escapement surveys. It is unknown if temperature related egg viability and/or adult mortality is an issue in the Tuolumne River.

Spawning Habitat Restoration
Spawning habitat restoration through gravel augmentation and channel narrowing to increase sediment transport is not expected to increase adult recruitment, because the loss

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[8]The Vernalis Adaptive Management Plan (e.g. VAMP) is a scientific study that evaluates the effects of Delta inflow, and outflow, upon fall-run Chinook salmon smolt survival.
[9] The VAMP survival estimates are highly affected by whether the tagged fish are recovered as juveniles in the Delta or as adults in the ocean harvest. Ocean recoveries suggest that juvenile survival rates through the Delta are higher that those based on Delta recoveries. For example, ocean coded wire tag recoveries for juvenile salmon released as part of South Delta flow evaluations at 5,000 cfs show a 25% survival rate as compared to a 14.5% survival rate for Delta recoveries.

of eggs and fry from degraded habitats and redd superimposition[10] appears to be inconsequential to the production of smolts in the Tuolumne River.

To examine this assumption, rotary screw trap captures in the Tuolumne River at the 7/11 and Grayson sites showed that many more juveniles were produced in spite of the degraded spawning habitat than survived to a smolt-size under the FSA flows schedules. In 1999 and 2000, only 0.4% and 1.4%, respectively, of the estimated number of juveniles passing the upper rotary screw trap at the 7/11 site (RM 38.6) survived to a smolt-sized fish that passed the downstream trap at Grayson (RM 5.2) in the Tuolumne River. The ineffectiveness of spawning habitat restoration is clearly evident in the Stanislaus River where rotary screw traps have monitored both the number of smolt out-migrants from Caswell State Park (RM 5) and the total number of juveniles migrating from the upper spawning reach at Oakdale (RM 40) in response to spawning habitat restoration at 18 sites in summer 1999 (Carl Mesick Consultants 2002). These studies indicate that although juvenile production increased by 32% from 1999 to 2000 in response to the gravel augmentation project, the increased juvenile production did not result in a corresponding increase in either the number of smolts migrating from the river at Caswell Park (Figure 17) or adult recruitment for the next three years (Mesick and Marston 2006).

Fish Predators

EA Engineering, Science, and Technology conducted riverwide electrofishing surveys in the Tuolumne River in spring 1989 and 1990 and concluded that largemouth and smallmouth bass are substantial predators of juvenile salmon (Turlock Irrigation District and Modesto Irrigation District 1991a). However, EA found that very few bass contained juvenile salmon in their stomachs except during May 1990 when 93,653 hatchery reared salmon smolts were released at Old La Grange Bridge for survival studies (Table 2). Subsequent studies have not determined whether restoring Special Run Pool 9 and isolating Special Run Pool 10 have reduced predation rates or improved the survival of juvenile salmon (Turlock Irrigation District and Modesto Irrigation District 2005).

[10] Spawning superimposition probably results in neither the mortality of a substantial number of incubating eggs nor reduction in adult recruitment in the San Joaquin Basin. High superimposition rates have been reported for the Stanislaus River (Mesick), American River (Vyverberg), and the Tuolumne River during the late-1980s drought when flow in the channel was confined to a narrow strip (EA Engineering, Science, and Technology. However, most superimposing redds are not superimposed exactly on top of each other but rather several feet to the side as well as several feet upstream or downstream of the original redd. Therefore, redd superimposition does not necessarily kill the eggs or entomb the alevins in the original egg pocket. Adult recruitment to the Tuolumne River is highly correlated with spring flow magnitude and not spawner density (Marston 2005, Mesick and Marston 2006) and many more juveniles are currently produced than can survive to a smolt-size under the existing base flows. Therefore, it is unlikely that redd superimposition, which presumably occurs when spawner densities are high, affects recruitment.

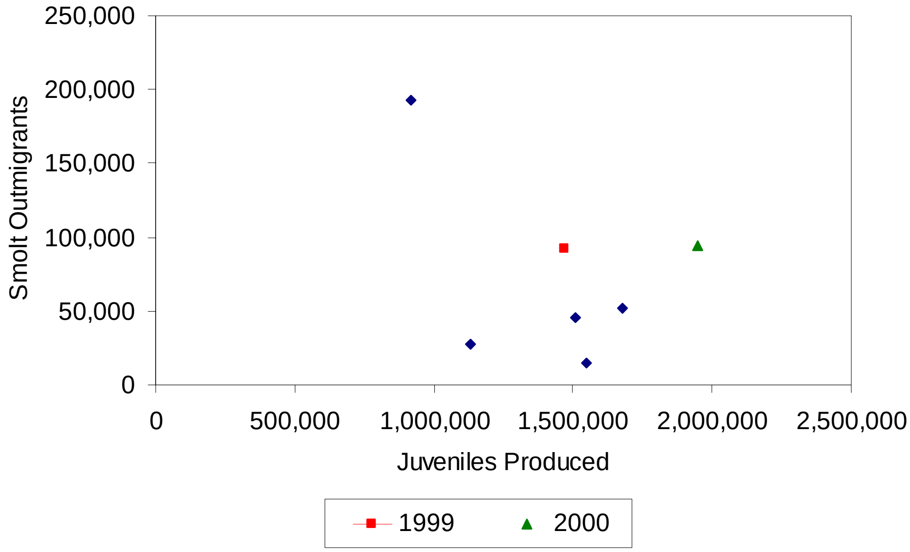

Figure 17. The estimated abundance of all sizes of juveniles that passed the Oakdale screw trap (RM 40) plotted with the estimated abundance of smolt out-migrants ($\geq$ 70 mm Fork Length) at the Caswell State Park screw traps (RM 5) in the Stanislaus River from 1998 to 2004. The Knights Ferry Gravel Replenishment Project (KFGRP) constructed 18 spawning beds in the Stanislaus River in summer 1999. A comparison of the 1999 and 2000 estimates provides the best evaluation of the effects of gravel augmentation on juvenile and smolt production, because they occurred immediately before and after the KFGRP and they were both affected by similar spring flows between February 1 and June 15 (7,394 cfs and 6,940 cfs, respectively) and similar numbers of spawners (2,600 and 3,200 Age 3 equivalent fish, respectively).

Table 2. EA Engineering, Science, and Technology predation studies in the lower Tuolumne River in 1989 and 1990.

Sampling Dates	La Grange Flows (cfs)	% Largemouth Bass with juvenile salmon in their stomachs	% Smallmouth Bass with juvenile salmon in their stomachs	Origin of Juvenile Salmon
4/19 to 5/17, 1989	40 – 121	3.6% (2/56)	8.6% (5/58)	Naturally Produced
1/29 to 3/27, 1990	142 – 174	2.1% (2/97)	3.1% (1/32)	Naturally Produced
4/25 to 4/28, 1990	187 – 207	2.6% (2/76)	6.3% (1/16)	Naturally Produced
5/2 to 5/4, 1990	299 -572	26% (40/152)	33.3% (6/18)	CWT Hatchery

Delta Exports

South Delta exports have long been identified as a limiting factor for Tuolumne River salmon recruitment. Federal pumping at Tracy began in the mid-1950's while State Pumping at the Harvey O. Banks facilities began in the late 1960's. Regressing Tuolumne River reconstructed brood year cohorts against spring combined State and Federal average annual spring pumping rates (Figure 18) suggests the Delta Pumping is not limiting production of adult salmon recruits in the Tuolumne River. Furthermore, reducing export rates from an average of 264% of Vernalis flows between 1980 and 1995 to an average of 43% of Vernalis flows between 1996 and 2002 during the mid-April to mid-May VAMP period did not increase Tuolumne River adult recruitment (see Figure 3 above).

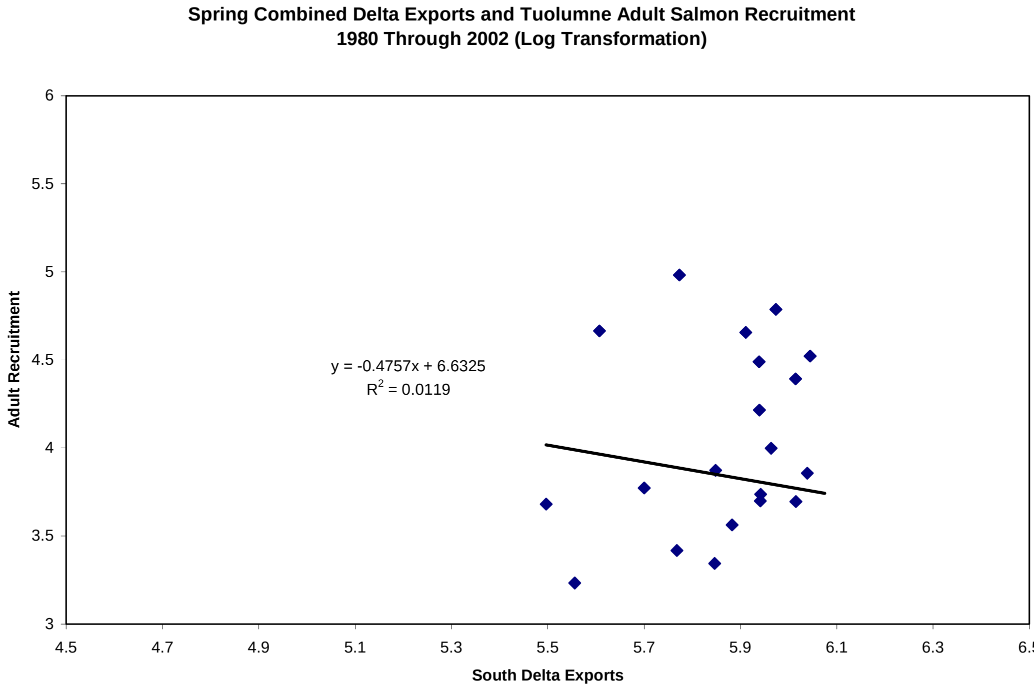

Figure 18. Combined South Delta spring exports plotted against Tuolumne River adult salmon recruitment (both data sets log transformed to base 10).

Fry Contribution

Since in some years millions of fry out-migrate from the Tuolumne River in the February and March time frame per rotary screw trap estimates, it is thought that these fry rear in the South Delta and successfully contribute, in large numbers, to adult recruitment. Large scale fry out-migration occurs in wet years on the Tuolumne River concurrent with early flood control releases. Wet year flood control releases on the Tuolumne River typically last throughout the spring and therefore presumably result in favorable conditions for fry rearing in the Delta to survive to a smolt-size. Although it is possible that fry contribute to adult recruitment in large numbers, particularly during wet years, the significant correlations between winter flows and smolt production, and between Tuolumne River smolt production and adult recruitment, suggest that the number of fry that out-migrate from the Tuolumne River to rear in the Delta explains little, if any, of the variation in Tuolumne River adult salmon recruitment. Further research is needed to determine whether out-migrating fry substantially contribute to adult recruitment.

Ocean Productivity

Two indices of ocean productivity conditions, which include the mean November to March values of the Pacific Interdecadal Oscillation (PDO) and the mean of the May to July values of the Pacific Fisheries Environmental Laboratory coastal upwelling index (PFEL Upwelling Index) for the San Francisco area (interpolated values to a latitude of

37.5 degrees North) were used in this analysis. The mean November to March values of the Pacific interdecadal Oscillation (PDO) is defined by Steven Hare as the leading principal component of North Pacific monthly sea surface temperature variability (poleward of 20N since 1900). The PFEL Upwelling Index is a measure of the intensity of large-scale, wind-induced coastal upwelling along the West Coast and is based on estimates of offshore Ekman transport driven by geostrophic wind stress (PFEL 2001). A mean index value for the May through July period because MacFarlane and Norton (2002) reported that this was when juvenile Chinook salmon entered the Gulf of the Farallones in 1997.

The PDO is highly correlated with sea surface temperatures and the ocean harvest of pacific salmon off the Alaska coast and the West coast (Mantua and others 1997). When sea surface temperatures are warm off the entire northeastern Pacific rim, PDO tends to be positive, Alaska landings of sockeye and pink salmon are relatively high, and West Coast landings of spring-run Chinook and coho salmon are low (Mantua and others 1997). Long-term records indicate that there are 15- to 25-year cycles of warm and cool periods that are strongly correlated with marine ecosystem productivity (Mantua and others 1997; Hollowed and others 2001). Cool productive cycles prevailed from 1947-1976 and a new cycle began in 1998, whereas warm unproductive cycles dominated from 1925-1946 and from 1977-1997 (Mantua and others 1997; Mantua and Hare 2002). The coastal warming that occurred in the mid-1970s is believed to have caused increased stratification in the California Current, a sharper thermocline with less vertical displacement of nutrient rich water due to coastal upwelling, a reduction in the duration of upwelling, conditions, and a reduction in nutrients and/or zooplankton abundance carried by the California Current (Francis and others 1998). In addition, the abundance of coastal euphausiids (*Thysanoessa spinifera*) declined whereas oceanic euphausiids (*T. pacifica*) increased (Francis and others 1998). Such changes are thought to affect salmon early in the marine life history (Hare and Francis 1995) and coastal invertebrate species are important prey for ocean-type juveniles, such as Central Valley fall-run Chinook salmon.

However, the PDO productivity cycles are not highly correlated with fall-run Chinook salmon production in the Central Valley. The USFWS ChinookProd estimates[11], which sums the escapement and ocean harvest estimates, for the entire Central Valley were compared between the productive and unproductive ocean periods. The mean in-river Central Valley wide Chinook production during the productive cool cycles was 31.1% and 139.3% higher for the 1952 to 1976 period and the 2000 to 2004 period, respectively, than during the unproductive warm cycle between 1979 and 1997 (Table 3). However, the higher production estimates during the 1952 to 1976 period may not be meaningful since a majority of the estimates (pre-1973) are not based on currently utilized mark-recapture techniques and so it is possible that the 31.1% increase is an artifact of different escapement survey methods. In addition, the higher production estimates during the 2000 to 2004 period are based on unusually large increases in several tributaries to the Sacramento Basin, including Battle Creek (592%), Clear Creek (198%), Butte Creek (438%), Feather River (150%), and American River (273%), that may be due to extensive

[11] USFWS Chinook Prod Spreadsheet is available at http://www.delta.dfg.ca.gov/afrp/

habitat restoration, improved flow releases, and/or hatchery production. The increase in the San Joaquin Basin during the 2000 to 2004 period was only 19%, which may be a result of improved base flows, habitat restoration, and hatchery production in the Mokelumne and Merced rivers. Moreover, the PDO and PFEL upwelling indices explained almost no variation in Tuolumne River recruitment. The spawner-recruit model with the PDO index had an adj-R^2 of 0.005 and a *P* value of 0.409. The spawner-recruit model with the PFEL upwelling index had an adj-R^2 of -0.015 and a *P* value of 0.457.

Ocean Harvest

Another factor thought to limit Tuolumne River adult salmon recruitment is ocean harvest by reducing the number of spawners such that the rearing habitat would not be saturated with juveniles. The Central Valley Index (CVI) of ocean harvest is estimated each year by the Pacific Fishery Management Council (PFMC 2006) by dividing total harvest south of Point Arena by the total hatchery and natural escapement to all Central Valley rivers. It is an index of the percentage of Central Valley Chinook salmon that are harvested each year, because the CVI does not include the Central Valley fish that are landed north of point Arena and it includes fish that originate from northern populations (e.g., the Klamath River) that are harvested south of point Arena. It is assumed that Tuolumne River adult salmon are exposed to the same fishing pressure as other Central Valley river produced salmon and therefore have the same chance of being caught. Regressing the CVI against Tuolumne River annual escapements from 1967 through 2004 (Figure 19) suggest strongly that ocean harvest is not influencing Tuolumne River adult salmon escapement. Moreover, 500 spawners should be enough to saturate the rearing habitat with juveniles (Mesick and Marston 2006) and low spawner abundance tends to result from low spring flows during extended droughts rather than from high ocean harvest rates.

Table 3. Fall-run Chinook salmon production, Sacramento Basin Water Year Index (WYI), San Joaquin Basin Water Year Index (WYI) for the unproductive ocean cycle between 1979 and 1997 and the productive cool ocean cycles between 1952 and 1976 and between 2000 and 2004.

	Central Valley Production	Sacramento Basin WYI	San Joaquin Basin WYI	Percent Change in Central Valley Production between Warm and Cool Period	Percent Change in Sacramento WYI between Warm and Cool Period	Percent Change in San Joaquin WYI between Warm and Cool Period
Warm Unproductive (1979-1997)	204,266	8.09	3.40	--	--	--
Cool Productive (1952-1976)	267,980	8.77	3.23	+31%	+8%	-5%
Cool Productive (2000-2004)	488,984	7.35	2.59	+139%	-9%	-24%

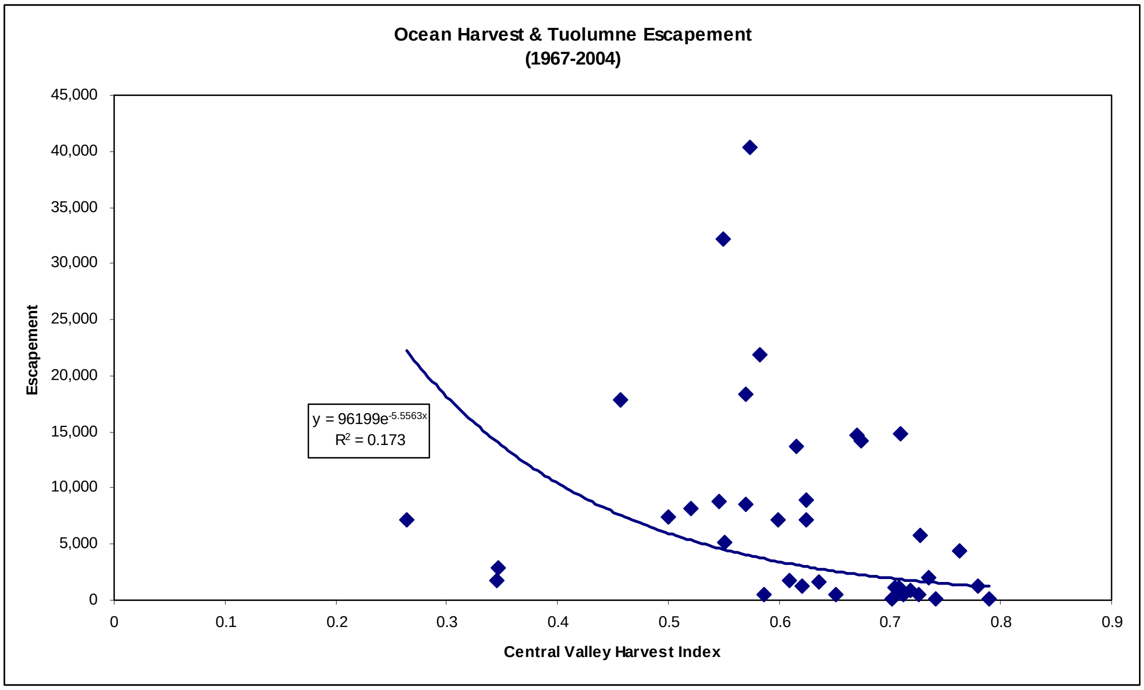

Figure 19. Central Valley Harvest Index Plotted with Tuolumne River Adult Salmon Escapement.

Riparian Vegetation

Another area of management concern is the health of riparian vegetation along the entire Tuolumne River corridor. A mature riparian canopy is important to juvenile salmon production by (a) providing detritus to the river as a food source for primary production food source for aquatic insects that juvenile salmonids prey upon, (b) provide a terrestrial insect food source, (c) provides shade to aid in providing cooler, higher quality, salmon spawning and rearing temperatures, and (d) providing large woody debris that provides and maintains in-river habitat complexity. Establishing riparian plant growth is dependent upon the rate and timing that flows are ramped down in late spring to support riparian seedling establishment. Research on a variety of cottonwood and willow species suggests that 1 to 1.5 inches/day is the maximum rate of water table decline for seedling survival (McBride et al. 1989; Segelquist et al. 1993; Mahoney and Rood 1993, 1998; Amlin and Rood 2002). However, a recent manipulation experiment of Fremont cottonwood, black willow, and narrow leaf willow seedlings found that water table declines of one inch or more resulted in 80% mortality within 60 days, even when the water table was maintained near the soil surface for several weeks before drawdown (Stillwater Sciences, unpublished data). Ramping rates of 100 to 300 cfs/day in the San Joaquin Basin are thought to prevent seedling desiccation under the assumed 1 inch/day maximum root growth rate. Recruitment flows may also have to occur from mid-April to late-May to improve cottonwood recruitment and from mid-May to late June to benefit black willow.

Rainbow Trout

Life History

The life history patterns of rainbow trout are highly variable and flexible, consisting of two basic patterns; anadromous and resident. Both these types of life-history stages exists in the same population, but dominance of one or the other commonly defines the population (Moyle 2002). Reports of migratory rainbow trout making extensive freshwater migrations are unfounded and extensive river migrations have not been demonstrated except in unusuall circumsantces such as in large lakes or reservoirs (Good et al. 2005). Although the anadromous and resident forms have long been taxonomically classified within the same species, in any given areas the exact relationship between the forms is not well understood (Good et al. 2005), and NMFS now distinquishes the two forms as separate distinct population segements (see FR 834, January 5, 2006). Recent studies have confirmed that genetic capability of anadromy is retained in rainbow trout for numerous generations (Thomas R. Payne & Associates and S.P. Cramer & Associates, 2005). Thus the protection of both life history patterns of rainbow trout is important to maintain the viability of the species.

Life history requirements and habitat needs of rainbow trout have been extensively studied and are not reviewed thoroughly here. Regardless of the life history form, for the first year or two, rainbow trout are found in cool, clear, fast-flowing permanent streams and rivers (Moyle 2002). As the agencies are primarily concerned with the anadromous form of rainbow trout, the following information primarily addresses life history traits, population levels, habitat needs, and limiting factors of the anadromous form in the Tuolumne River and San Joaquin basin.

Steelhead can be divided into two life history types, based on their state of sexual maturity at the time of river entry and the duration of their spawning migration, stream-maturing and ocean-maturing. Stream-maturing steelhead enter freshwater in a sexually immature condition and require several months to mature and spawn, whereas ocean-maturing steelhead enter freshwater with well-developed gonads and spawn shortly after river entry. These two life history types are more commonly referred to by their season of freshwater entry (*i.e.*, summer (stream-maturing) and winter (ocean-maturing) steelhead). Only winter steelhead currently are found in Central Valley rivers and streams (McEwan and Jackson 1996), although there are indications that summer steelhead were present in the Sacramento river system prior to the commencement of large-scale dam construction in the 1940s (Interagency Ecological Program (IEP) Steelhead Project Work Team 1999). At present, summer steelhead are found only in North Coast drainages, mostly in tributaries of the Eel, Klamath, and Trinity River systems (McEwan and Jackson 1996).

Central Valley steelhead generally leave the ocean from August through April (Busby *et al.* 1996), and spawn from December through April with peaks from January though March in small streams and tributaries where cool, well oxygenated water is available year-round (McEwan and Jackson 1996; Hallock *et al.* 1961)(Table 4). Timing of upstream migration is correlated with higher flow events, such as freshets or sand bar breaches, and associated lower water temperatures. Unlike Pacific salmon, steelhead are iteroparous, or capable of spawning more than once before death (Busby *et al.* 1996). However, it is rare for steelhead to spawn more than twice before dying; most that do so are females (Busby *et al.* 1996). Iteroparity is more common among southern steelhead populations than northern populations (Busby *et al.* 1996). Although one-time spawners are the great majority, Shapolov and Taft (1954) reported that repeat spawners are relatively numerous (17.2 percent) in California streams.

The female selects a site where there is good intergravel flow, then digs a redd and deposits eggs while an attendant male fertilizes them. The eggs are then covered with gravel when the female begins excavation of another redd just upstream. The length of time it takes for eggs to hatch depends mostly on water temperature. Hatching of steelhead eggs in hatcheries takes about 30 days at 51 °F. Fry emerge from the gravel usually about four to six weeks after hatching, but factors such as redd depth, gravel size, siltation, and temperature can speed or retard this time (Shapovalov and Taft 1954). The newly emerged fry move to the shallow, protected areas associated with the stream margin (McEwan and Jackson 1996) and they soon move to other areas of the stream and establish feeding locations, which they defend (Shapovalov and Taft 1954).

Steelhead rearing during the summer takes place primarily in higher velocity areas in pools, although young-of-the-year also are abundant in glides and riffles. Productive steelhead habitat is characterized by complexity, primarily in the form of large and small woody debris. Cover is an important habitat component for juvenile steelhead both as velocity refugia and as a means of avoiding predation (Meehan and Bjornn 1991).

Juvenile steelhead emigrate episodically from natal streams during fall, winter, and spring high flows. Emigrating CV steelhead use the lower reaches of the Sacramento River and the Delta for rearing and as a migration corridor to the ocean. Juvenile Central Valley steelhead feed mostly on drifting aquatic organisms and terrestrial insects and will also take active bottom invertebrates (Moyle 2002).

Some may utilize tidal marsh areas, non-tidal freshwater marshes, and other shallow water areas in the Delta as rearing areas for short periods prior to their final emigration to the sea. Hallock *et al.* (1961) found that juvenile steelhead in the Sacramento River basin migrate downstream during most months of the year, but the peak period of emigration occurred in the spring, with a much smaller peak in the fall. Nobriga and Cadrett (2000) also have verified these temporal findings based on analysis of captures at Chipps Island, Susuin Bay.

Table 4. The temporal occurrence of adult (a) and juvenile (b) CV steelhead in the Central Valley. Darker shades indicate months of greatest relative abundance.

(a) Adult

Location	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
[1,3]Sac. River	L	L	L	L	L	L						L	L	L	L	M	M	H	H	M	L	L	L	L
[2,3]Sac R at Red Bluff	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	M	M	H	M	L	L	L	L
[4]Mill, Deer Creeks			H	M	M	L	L	L	L	L	L	L								H	H	M	M	M
[6]Sac R. at Fremont Weir	L	L	L	L											M	M	H	H	M	M	L	L	L	L
[6]Sac R. at Fremont Weir	L	L	L	L											M	M	H	H	M	M	L	L	L	L
[7]San Joaquin River	M	M	M	M	M	M							L	L	L	L	M	M	M	M	M	M	H	H

(b) Juvenile

Location	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
[1,2]Sacramento River	L	L	L	L	M	M	M	M	M	M	M	M	L	L	L	L	L	L	M	M	M	M	L	L
[2,8]Sac. R at Knights Land	L	L	L	L	H	H	L	L	L															L
[9]Sac. River @ KL	M	M	M	M	H	H	H	H	M	M											L	L	L	L
[10]Chipps Island (wild)	L	L	L	L	H	H	H	H	M	M	M	M	L	L					L	L	L	L	L	L
[8]Mossdale							H	H	H	H														
[11]Woodbridge Dam	M	M	M	M	M	M	M	M	M	M	M	M	M	M										
[12]Stan R. at Caswell	L	L	M	M	H	H	M	M	M	M	L	L												
[13]Sac R. at Hood	L	L	H	H	H	H	H	H	H	H											L	L	L	L

Source: [1]Hallock 1961; [2]McEwan 2001; [3]USFWS unpublished data; [4]CDFG 1995; [5]Hallock *et a*l. 1957; [6]Bailey 1954; [7]CDFG Steelhead Report Card Data; [8]CDFG unpublished data; [9]Snider and Titus 2000; [10]Nobriga and Cadrett 2001; [11]Jones & Stokes 2002; [12]S.P. Cramer and Associates, Inc. 2000 and 2001; [13]Schaffter 1980

Relative Abundance: H = High   M = Medium   L = Low

CV steelhead historically were well-distributed throughout the Sacramento and San Joaquin Rivers (Busby *et al.* 1996) and were found from the upper Sacramento and Pit River systems (now inaccessable due to Shasta and Keswick Dams) south to the Kings and possibly the Kern River systems (now inaccessible due to extensive alterations from numerous water diversion projects) and in both east- and west-side Sacramento River tributaries (Yoshiyama *et al.* 1996). The present distribution has been greatly reduced (McEwan and Jackson 1996). Historic CV steelhead run sizes are difficult to estimate given the paucity of data, but may have approached 1 to 2 million adults annually (McEwan 2001). By the early 1960s the steelhead run size had declined to about 40,000 adults (McEwan 2001). Over the past 30 years, the naturally-spawned steelhead populations in the upper Sacramento River have declined substantially. Hallock *et al.* (1961) estimated an average of 20,540 adult steelhead through the 1960s in the Sacramento River, upstream of the Feather River. Steelhead counts at the RBDD declined from an average of 11,187 for the period of 1967 to 1977, to an average of approximately 2,000 through the early 1990s, with an estimated total annual run size for the entire Sacramento-San Joaquin system, based on RBDD counts, to be no more than 10,000 adults (McEwan and Jackson 1996, McEwan 2001). Steelhead escapement surveys at RBDD ended in 1993 due to changes in dam operations.

Recent estimates from trawling data in the Delta indicate that approximately 100,000 to 300,000 smolts emigrate to the ocean per year representing approximately 3,600 female Central Valley steelhead spawners in the Central Valley basin (Good *et al*. 2005). This can be compared with McEwan's (2001) estimate of one million to two million spawners before 1850, and 40,000 spawners in the 1960s."

Existing wild steelhead stocks in the Central Valley are mostly confined to the upper Sacramento River and its tributaries, including Antelope, Deer, and Mill Creeks and the Yuba River. Populations may exist in Big Chico and Butte Creeks and a few wild steelhead are produced in the American and Feather Rivers (McEwan and Jackson 1996). Recent snorkel surveys (1999 to 2002) indicate that steelhead are present in Clear Creek (J. Newton, USFWS, pers. comm. 2002, as reported in Good *et al*. 2005). Because of the large resident *O. mykiss* population in Clear Creek, steelhead spawner abundance has not been estimated.

Recent monitoring has detected small self-sustaining populations of steelhead in the Stanislaus, Mokelumne, Calaveras, and other streams previously thought to be devoid of steelhead (McEwan 2001). On the Stanislaus River, steelhead smolts have been captured in rotary screw traps at Caswell State Park near the mouth of the river and Oakdale each year since 1995 (S.P. Crammer and Associates Inc. 2000, 2001). It is possible that naturally-spawning populations exist in many other streams but are undetected due to lack of monitoring programs (IEP Steelhead Project Work Team 1999). Incidental catches and observations of steelhead juveniles also have occurred on the Tuolumne and Merced Rivers during fall-run Chinook salmon monitoring activities, indicating that steelhead are widespread, throughout accessible streams and rivers in the Central Valley (Good *et al*. 2005). CDFG staff have prepared juvenile migrant Central Valley steelhead catch summaries on the San Joaquin River near Mossdale representing migrants from the Stanislaus, Tuolumne, and Merced Rivers. Based on trawl recoveries at Mossdale between 1988 and 2002, as well as rotary screw trap efforts in all three tributaries, CDFG staff stated that it is "clear from this data that rainbow trout do occur in all the tributaries as migrants and that the vast majority of them occur on the Stanislaus River" (Letter from Dean Marston, CDFG, to Madelyn Martinez, NMFS, January 9, 2003). The documented returns on the order of single fish in these tributaries suggest that existing populations of Central Valley steelhead on the Tuolumne, Merced, and lower San Joaquin Rivers are severely depressed.

Limiting Factors
A number of documents have addressed the history of human activities, present environmental conditions, and factors contributing to the decline Central Valley steelhead. For example, NMFS prepared range-wide status reviews for west coast steelhead (Busby *et al*. 1996). NMFS also assessed the factors for steelhead decline in supplemental documents (NMFS 1996). Information also is available in Federal Register

notices announcing ESA listing proposals and determinations for some of these species and their critical habitat (e.g., 58 FR 33212; 59 FR 440; 62 FR 24588; 62 FR 43937; 63 FR 13347; 64 FR 24049; 64 FR 50394; 65 FR 7764). The following general description is based on a summarization of these documents.

Hydropower, flood control, and water supply dams, and other municipal and private entities have permanently blocked or hindered salmonid access to historical spawning and rearing grounds resulting in the complete loss of substantial portions of spawning, rearing, and migration habitat. Yoshiyama *et al*. (1996) surmised that steelhead habitat loss was even greater than salmon loss, as steelhead migrated farther into drainages. The California Advisory Committee on Salmon and Steelhead Trout (1988) estimated that there has been a 95 percent reduction of Central Valley anadromous fish spawning habitat.

In general, large dams on every major tributary to the Sacramento River, San Joaquin River, and the Delta block steelhead access to the upper portions of their respective watersheds. Friant Dam construction in the mid 1940s has been associated with the elimination of anadromous salmonid runs in the San Joaquin River upstream of the Merced River. On the Stanislaus River, construction of Goodwin Dam (1912), Tulloch Dam (1957), and New Melones Dam (1979) blocked both spring- and fall-run Chinook salmon as well as CV steelhead. Similarly, La Grange Dam (1893) and New Don Pedro Dam (1971) blocked salmon and steelhead from upstream spawning areas on the Tuolumne River. Upstream migration on the Merced River was blocked in 1910 by the construction of Merced Falls and Crocker-Huffman Dams and later New Exchequer Dam (1967) and McSwain Dam (1967). The loss of substantial habitat above dams also has resulted in decreased juvenile and adult steelhead survival during migration, and in many cases, had resulted in the dewatering and loss of important spawning and rearing habitats.

Changes in the thermal profiles and hydrographs of the Central Valley rivers have presumably subjected salmonids to strong selective forces (Slater 1963). The degree to which current life history traits reflect predevelopment characteristics is largely unknown, especially since most of the habitat degradation occurred before salmonid studies were undertaken late in the nineteenth century. Increased temperatures as a result of reservoir operations during winter and fall can affect emergence rates of salmoninds; thereby, significantly altering the life history of a species (California Bay-Delta Authority 2005). Shifts in life history have the potential to seriously affect survival (California Bay-Delta Authority 2005). In addition, Brown and May (2000) found stream regulation to be associated with declines in benthic macroinvertebrate communities in Central Valley rivers. Macroinvertebrates are key prey species for salmonids.

Water diversions for irrigated agriculture, municipal and industrial use, and managed wetlands are found throughout the Central Valley. Hundreds of small and medium-size water diversions exist along the Sacramento River, San Joaquin River, and their tributaries. Although efforts have been made in recent years to screen some of these diversions, many remain unscreened. Depending on the size, location, and season of operation, these unscreened diversions entrain and kill many life stages of aquatic species, including juvenile salmonids. For example, as of 1997, 98.5 percent of the 3,356 diversions included in a Central Valley database were either unscreened or screened insufficiently to prevent fish entrainment (Herren and Kawasaki 2001).

Increased sedimentation resulting from agricultural and urban practices within the Central Valley is a primary cause of salmonid habitat degradation (NMFS 1996). Sedimentation can adversely affect salmonids during all freshwater life stages by: clogging or abrading gill surfaces, adhering to eggs, hampering fry emergence (Phillips and Campbell 1961), burying eggs or alevins, scouring and filling in pools and riffles, reducing primary productivity and photosynthesis activity, and affecting inter-gravel permeability and dissolved oxygen levels. Excessive sedimentation over time can cause substrates to become embedded, which reduces successful salmonid spawning and egg and fry survival.

Land use activities such as agricultural conversion, and industrial and urban development continue to have large impacts on salmonid habitat in Central Valley watersheds, affecting spawning habitat, freshwater rearing habitat, freshwater migration corridors, estuarine areas, and nearshore marine areas. While historical uses of riparian areas (e.g., wood cutting, clearing for agricultural uses) have substantially decreased, urbanization still poses a serious threat to remaining riparian areas. Riversides are desirable places to locate homes, businesses, and industry. Further, development within the flood plain results in vegetation removal, stream channelization, habitat instability, and point and non-point source pollution (NMFS 1996). In addition, the armoring, revetment, and narrowing of stream banks tends to reduce the amount of habitat per unit channel length (Sweeney *et al*. 2004). As a result of river narrowing, benthic habitat decreases and the number of macroinvertebrates, such as stoneflies and mayflies, per unit channel length decreases affecting salmonid food supply.

Point source (PS) and non-point source pollution (NPS) occurs at almost every point that urbanization activity influences the watershed. Impervious surfaces (*i.e*. concrete) reduce water infiltration and increase runoff, thus creating greater flood hazard (NMFS 1996). Flood control and land drainage schemes may increase the flood risk downstream by concentrating runoff. A flashy discharge pattern results in increased bank erosion with subsequent loss of riparian vegetation, undercut banks and stream channel widening. Runoff from residential and industrial areas also contributes to water quality degradation (California Regional Water Quality Control Board-Central Valley Region 1998). Urban stormwater runoff contains pesticides, oil, grease, heavy metals, polynuclear aromatic hydrocarbons, other organics and nutrients (California Regional Water Quality Control Board-Central Valley Region 1998) that contaminate drainage waters and destroy aquatic life necessary for salmonid survival (NMFS 1996). In addition, juvenile salmonids are exposed to increased water temperatures as a result of thermal inputs from municipal, industrial, and agricultural discharges.

Past mining activities routinely resulted in the removal of spawning gravels from streams, channelization of streams from dredging activities, and leaching of toxic effluents into streams. Many of the effects of past mining operations still impact steelhead habitat today. While some of this mining habitat has been repaired on the Tuolumne and Merced rivers, a substantial portion of the habitat is still degraded as a result of past activities.

The world is about 1.3 °F warmer today than a century ago and the latest computer models predict that, without drastic cutbacks in emissions of carbon dioxide and other gases released by the burning of fossil fuels, the average global surface temperature may raise by two or more degrees in the 21st century (IPCC, 2001). Much of that increase will likely occur in the oceans, and evidence suggests that the most dramatic changes in ocean temperature are now occurring in the Pacific (Noakes 1998). Using objectively analyzed data Huang and Liu (2000) estimated a warming of about 0.9 °F per century in the Northern Pacific Ocean.

Sea levels are expected to rise by 0.5 to 1.0 meters in the northeastern Pacific coasts in the next century, mainly due to warmer ocean temperatures, which lead to thermal expansion much the same way that hot air expands. This will cause increased sedimentation, erosion, coastal flooding and permanent inundation of low-lying natural ecosystems (*e.g*., salt marsh, riverine, mud flats) affecting salmonid PCEs. Increased winter precipitation, decreased snow pack, permafrost degradation and glacier retreat due to warmer temperatures will cause landslides in unstable mountainous regions, and destroy fish and wildlife habitat, including salmon-spawning streams. Glacier reduction could affect the flow and temperature of rivers and streams that depend on glacier water, with negative impacts on fish populations and the habitat that supports them.

Summer droughts along the south coast and in the interior of the northwest Pacific coastlines will mean decreased stream flow in those areas, decreasing salmonid survival and reducing water supplies in the dry summer season when irrigation and domestic water use are greatest. Global warming may also change the chemical composition of the water that fish inhabit: the amount of oxygen in the water may decline, while pollution, acidity, and salinity levels may increase. This will allow for more invasive species to over take native fish species and impact predator-prey relationships (Stachowicz *et al.*, 2002 and Peterson and Kitchell, 2001).

An alarming prediction is the fact that Sierra snow packs are expected to decrease with global warming and that the majority of runoff in California will be from rainfall in the winter rather than from melting snow pack in the mountains. This will alter river runoff patterns and transform the tributaries that feed the Central Valley from a spring/summer snowmelt dominated system to a winter rain dominated system. It can be hypothesized that summer temperatures and flow levels will become unsuitable for salmonid survival. The cold snowmelt that furnishes the late spring and early summer runoff will be replaced by warmer precipitation runoff. This should truncate the period of time that suitable cold-water conditions exist below existing reservoirs and dams due to the warmer inflow temperatures to the reservoir from rain runoff. Without the necessary cold water pool developed from melting snow pack filling reservoirs in the spring and early summer, late summer and fall temperatures below reservoirs, such as Lake Shasta, could potentially rise above thermal tolerances for juvenile and adult salmonids (*i.e.*

Sacramento River winter-run Chinook salmon and CV steelhead) that must hold below the dam over the summer and fall periods.

During flood events, land disturbances resulting from logging, road construction, mining, urbanization, livestock grazing, agriculture, fire, and other uses may contribute sediment directly to streams or exacerbate sedimentation from natural erosive processes (California Advisory Committee on Salmon and Steelhead Trout 1988, NMFS 1996). Sedimentation of stream beds has been implicated as a principle cause of declining salmonid populations through-out their range. In addition to problems associated with sedimentation, flooding can cause scour and redeposition of spawning gravels in typically inaccessible areas. As streams and pools fill in with sediment, flood flow capacity is reduced. Such changes cause decreased stream stability and increased bank erosion, and subsequently exacerbate existing sedimentation problems (NMFS 1996). All of these sources contribute to the sedimentation of spawning gravels and filling of pools and estuaries used by all anadromous salmonids. Channel widening and loss of pool-riffle sequence due to aggradation has damaged spawning and rearing habitat of all salmonids.

Unusual drought conditions may warrant additional consideration in California. Flows in 2001 were among the lowest flow conditions on record in the Central Valley. The available water in the Sacramento watershed and San Joaquin watershed was 70 percent and 66 percent of normal, according to the Sacramento River Index and the San Joaquin River Index, respectively. Back-to-back drought years could be catastrophic to small populations of steelhead that are dependent upon reservoir releases for their success. Therefore, reservoir carryover storage (usually referred to as end-of-September storage) is a key element in providing adequate reserves to protect salmon and steelhead during extended drought periods. In order to buffer the effect of drought conditions and over allocation of resources, NMFS in the past has recommended that minimum carryover storage be maintained in Shasta and other reservoirs to help alleviate critical flow and temperature conditions in the fall.

The extensive introduction of NIS have dramatically altered the biological relationships between and among salmonids and the natural communities that share rivers (NMFS 1998). As currently seen in the San Francisco Estuary, non-native invasive species (NIS) can alter the natural food webs that existed prior to their introduction. Perhaps the most significant example is illustrated by the Asiatic freshwater clams *Corbicula fluminea* and *Potamocorbula amurensis*. The arrival of these clams in the estuary disrupted the normal benthic community structure and depressed phytoplankton levels in the estuary due to the highly efficient filter feeding of the introduced clams (Cohen and Moyle 2004). The decline in the levels of phytoplankton reduces the population levels of zooplankton that feed upon them, and hence reduces the forage base available to salmonids transiting the Delta and San Francisco Estuary which feed either upon the zooplankton directly or their mature forms. This lack of forage base can adversely impact the health and physiological condition of these salmonids as they emigrate through the Delta region to the Pacific Ocean.

Attempts to control the NIS also can adversely impact the health and well being of salmonids within the affected water systems. For example, the control programs for the invasive water hyacinth and *Egeria densa* plants in the Delta must balance the toxicity of the herbicides applied to control the plants to the probability of exposure to listed salmonids during herbicide application. In addition, the control of the nuisance plants has certain physical parameters that must be accounted for in the treatment protocols, particularly the decrease in DO resulting from the decomposing vegetable matter left by plants that have died.

Water Temperature

Water temperature is thought to be a population limiting factor for both salmon and rainbow trout in the Tuolumne River. However, it is unknown how, or if, water temperature is limiting salmonid production in the Tuolumne River. Recently a comprehensive water temperature computer modeling simulation exercise was conducted for the Stanislaus River to evaluate how water operations on the Stanislaus influenced water temperatures in the Stanislaus. As part of this assessment, a literature review was conducted, and CALFED peer reviewed (Deas et.al. 2004), to identify water temperature criteria for both salmon and steelhead to evaluate how water temperature response might influence salmon and steelhead by life history stage. The Stanislaus River Water Temperature Peer Review Panel adopted the Environmental Protection Agency water temperature for fall-run Chinook salmon and steelhead (Table 5) finding no variation in temperature exposure tolerance between northern and southern Chinook salmon stocks.

Table 5. Temperature criteria/goal for identified species and lifestages in the Stanislaus River (after EPA, 2003 as presented in Deas et. al. 2004)

Stanislaus R. Terminology	EPA-based Recommended Temperature Criteria/Goals to Protect Salmon and Trout (Criteria are based on the 7-day average of the daily maximum values)
Adult migration	<64°F (<18°C) for salmon and trout migration
	<68°F (<20°C) for salmon and trout migration - generally in the lower part of river basins that likely reach this temperature naturally, if there are cold-water refugia available [but no evidence of such refugia are available for the Stanislaus River]
Incubation	<55°F (<13°C) for salmon and trout spawning, egg incubation, and fry emergence
Juvenile rearing (early year)	<61°F (<16°C) for salmon "core" juvenile rearing - generally in the mid- to upper part of river basins
Smoltification	<59°F (<15°C) for salmon smoltification
	<57°F (<14°C) for steelhead smoltification (for composite criteria steelhead conditions are applied)
Juvenile rearing (late year)	<64°F (<18°C) for salmon and steelhead migration plus non-Core Juvenile Rearing - generally in the lower part of river basins

Modeling results from the Stanislaus River indicate that water temperatures can exceed threshold values for salmonids, in some years, during the spring, summer and fall time periods. The degree of water temperature violation (extent of threshold exceedence) is dependent upon ambient air temperature, reservoir storage, reservoir release location and release volume (unpublished data). The water temperature model prepared for the Stanislaus is being applied to the Tuolumne, but no results have been produced to date. For Tuolumne River salmon, from information provided above, the smolt life history stage is critically important to adult recruitment abundance. Preliminary assessment of water temperatures during this time period suggests that flow volume (Figure 20) is important to conveying a suitable out-migration temperature for Tuolumne River salmon smolts.

For rainbow trout, Adult *O. mykiss* spawn in the San Joaquin tributaries between January and late-May and so water temperatures when eggs are incubating in late spring is a management concern. The optimum temperature range for steelhead egg incubation is estimated to be 46ºF to 52ºF based on various studies (Reiser and Bjornn 1979, Bovee 1978, Bell 1986, Leidy and Li 1987). Egg mortality may begin at temperatures above 56ºF (McEwan and Jackson 1996). Adult straying and egg viability may be affected by flow if (a) water temperatures in the Delta affect egg viability and (b) flow and export rates in the Delta affect the number of San Joaquin adults that stray to the Sacramento Basin. If true, then managing flow and Delta export rates may be an important tool for maximizing the number of adult fish with viable eggs that return to the Tuolumne River each year.

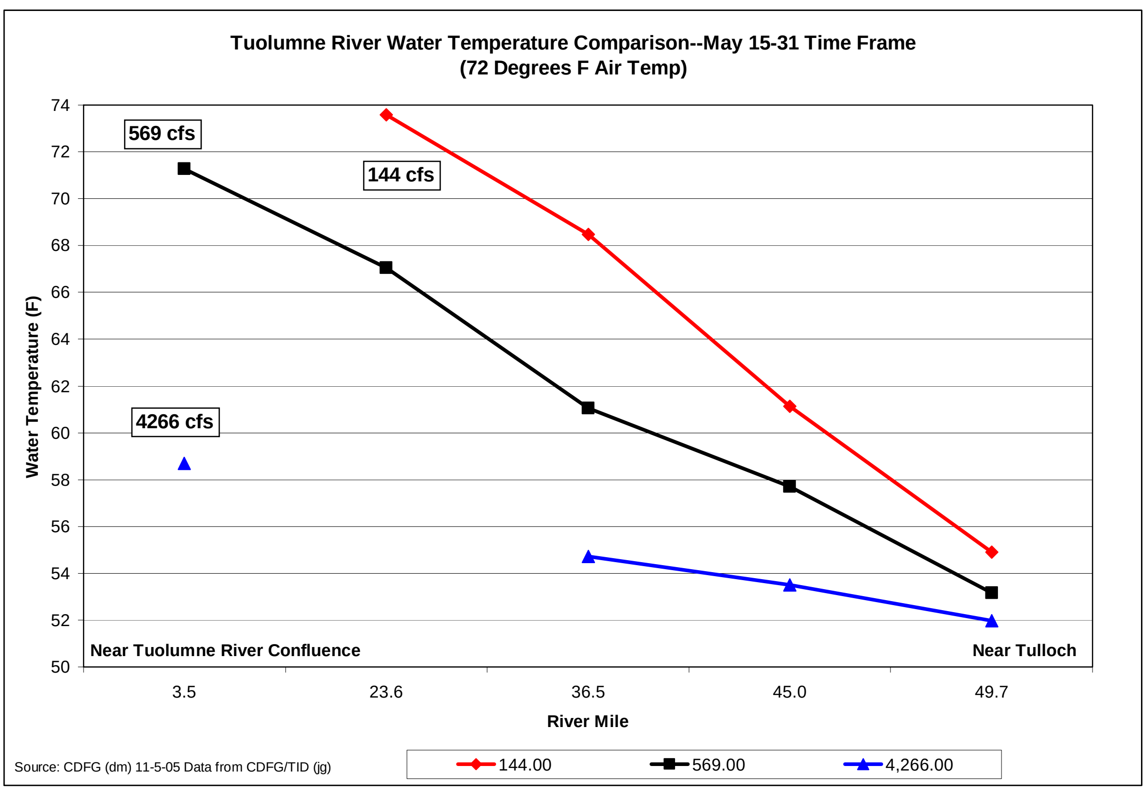

Figure 20. Tuolumne River Late Spring Flow and Water Temperature.

Management Conceptual Models

Chinook Salmon Model

The Agencies' Salmon Model (Figure 21) is life history based and includes the following six components in order of highest to lowest priority: (1) smolt survival in the Tuolumne River and Delta is primarily affected by instream flow releases from April 1 to June 15; (2) survival of juveniles to the smolt-stage in the Tuolumne River is primarily affected by instream flow releases between early-February and late-May (3) survival of Tuolumne River juveniles to the smolt-stage in the Delta is primarily affected by instream flow releases between early-February and late-May; (4) the production of early migrating juveniles, which have the greatest likelihood of surviving to adulthood, is affected by fall flow releases that affect straying rates, the viability of eggs in early migrating adults, and possibly redd superimposition rates; (5) restoration of physical habitat and fluvial geomorphic processes intended to increase egg survival to emergence or reduce predation by black bass will not substantially increase adult recruitment; and (6) factors that affect salmonid survival in the ocean are relatively unimportant.

To evaluate the mechanism(s) between flow and the survival of juvenile Chinook salmon, the Agencies provide hypotheses and recommended study elements for developing a long-term monitoring program.

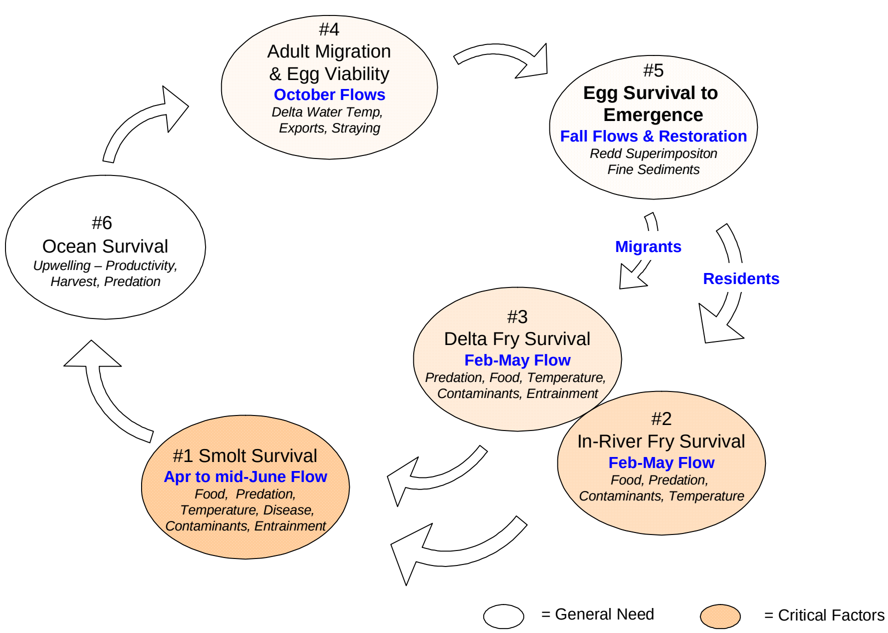

Figure 21. The Agencies' conceptual model explaining how flow, restoration, and other factors can best be managed to substantially increase the abundance of fall-run Chinook salmon in the lower Tuolumne River. The importance of the factors is shown numerically by assigning # 1 to the most critical factor and #6 to the least critical factor.

Life History Components:

1. **Smolt Outmigration**: *High flows between early April and mid-June are the primary determinant of smolt survival and adult recruitment in the Tuolumne River.* The specific mechanism(s) by which flow affects smolt survival is unknown, and it is likely that there are several mortality factors that are ameliorated by increased spring flow. It is assumed that:
   a. Water quality (e.g., water temperature, contaminants, and dissolved oxygen) in the lower river and Delta improves which reduces mortality causal factors (e.g., disease, contaminants, and starvation); Smoltification and out-migration transit time are reduced through the lower Tuolumne River and Delta;
   b. Predation, by native Sacramento pikeminnow (*Ptychocheilus grandis*) and introduced black bass and striped bass (*Morone saxatilis*), is reduced as water temperature declines, water quality improves, water velocity increases, and flood-related turbidity increases;
   c. Entrainment and impingement is reduced at diversions in the lower river and Delta (e.g., by reducing the proportion of flow diverted, the percentage of juveniles entrained or impinged is also reduced).

2. **In-River Rearing**: *High flows between early-February and late-May are another primary determinant of the number of juvenile salmon that survive to smolt size in the Tuolumne River and contribute to adult recruitment.* It is assumed that when high flows begin in February and extend into late-May, a higher percentage of juveniles survive as a result of
   a. increased rearing habitat quantity and quality as floodplain habitat increases;
   b. increased food availability from inundated floodplains,
   c. improved water quality (including water temperature, contaminants, and dissolved oxygen) improves which reduces mortality from other stressors (e.g., disease, contaminates, and starvation), and
   d. reduced predation by Sacramento pikeminnow, black bass and striped bass.
3. **Delta Rearing:** *High flows between early-February and late-May contribute to a lessor degree the abundance number of fry and parr that survive their migration through the Tuolumne River and then rear to a smolt size in the San Joaquin River and Delta.* It is assumed that few of these downstream rearing fry survive except during wet years and so this is a secondary source of adult recruitment.
4. **Fall flows:** *Fall flows improve egg viability and minimize straying of early arriving adult salmon.* It is assumed that adult spawning, and eggs survival to emergence improves as fall adult attraction flows increase and as sufficient spawning habitat quality flow levels occur (e.g. to maximize useable spawning habitat area defined by having preferred water velocities, depth, and temperature.
5. **Habitat Restoration:** *Restoration of physical habitat and fluvial geomorphic processes intended to increase egg survival to emergence do not substantially increase adult recruitment.* It is assumed that adult salmon need suitable

attraction flows from the Tuolumne River into the South Delta to emigrate into the Tuolumne River. It is also assumed that salmon need sufficient base spawning flow levels to adequately seed the Tuolumne River with a sufficient number of eggs to produce an adequate number of fry to allow for, given a sufficient level of winter and spring period flow, and adequate number of out-migrating smolts. It is assumed that current water year type based fall attraction flow volumes and timing, and minimum spawning base flow levels, provide sufficient adult attraction and spawning habitat quality.

6. **Indices of ocean conditions:** *Indices of ocean conditions, such as the mean November to March values of Pacific interdecadal oscillation and the mean May to July values of the Pacific Fisheries Environmental Laboratory coastal upwelling index, are not correlated with adult recruitment in the Tuolumne River (Mesick and Marston 2006).* It is assumed that no management focus addressing these possible production parameters is necessary.
7. **Ocean Harvest:** *Ocean harvest does not materially influence adult escapement into the Tuolumne River*. It is assumed that Tuolumne River origin salmon caught in the ocean fisheries are caught in proportion to the number of juvenile salmon (smolts) produced in the Tuolumne River.

Rainbow Trout Model

The Agencies' migratory rainbow model separates the life history components into critical factors and general needs (Figure 22). There are two critical factor components in the model: (1) survival of downstream migrating smolts in the Tuolumne River and Delta is primarily affected by flow between early-January and mid-June; and (2) juveniles survival is dependent on adequate flow between February and November during the entire two- to three-year rearing period as it affects summer water temperatures, food, and predation. The model also includes two general need components, which must be managed to sustain the population: (1) egg survival to emergence is primarily affected by water temperatures during late spring and degraded spawning habitats and (2) adult straying and the viability of eggs in upmigrating adults are affected by low flows and high Delta exports primarily from December through May. The Agencies believe that factors that affect steelhead survival in the ocean are relatively unimportant for the same reason cited for Salmon.

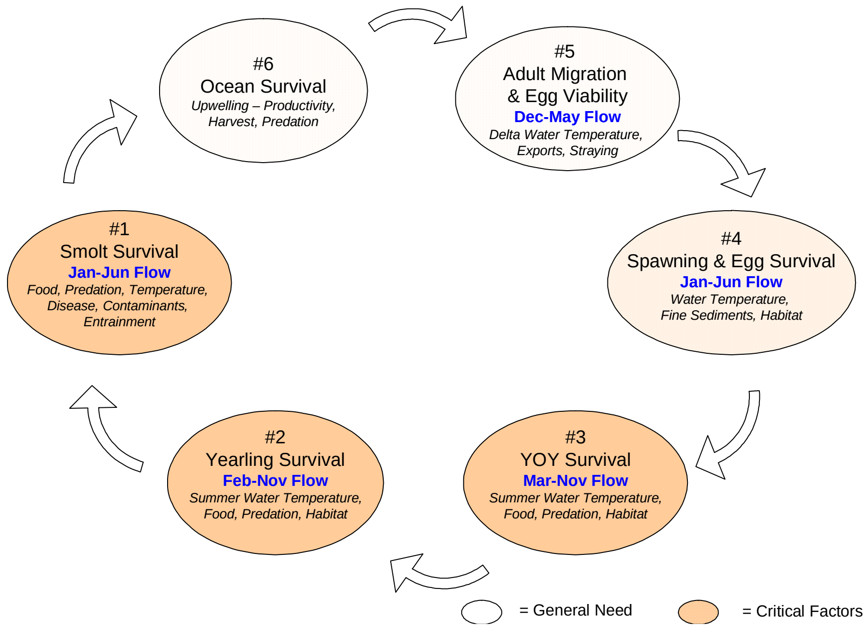

Figure 22. The Agencies' conceptual model explaining how flow, restoration, and other factors can best be managed to protect migratory rainbow trout in the lower Tuolumne River. The importance of the factors is shown numerically by assigning # 1 to the most critical factor and #6 to the least critical factor.

Life History Components

1. **Smolt Outmigration**: *High flows between January and mid-June are a primary determinant of smolt survival and adult recruitment in the Tuolumne River*. The mechanism(s) by which flow affects steelhead smolt survival is unknown. It is assumed that flow levels that increase salmon smolt production will also increase steelhead smolt production as the two species are closely related and adapted to the same circumstances in the Tuolumne River.
2. **Summer Juvenile Rearing:** *Summer water temperatures downstream to the Roberts Ferry Bridge are a primary determinant of the number of juveniles that survive to a smolt size in the Tuolumne River*. It is assumed that sustaining a steelhead population in the Tuolumne River requires that suitable water temperatures are provided at least to Roberts Ferry Bridge every year. It is assumed that most, if not all, steelhead smolts require two rearing summers before beginning their downstream migration. It is assumed that most of the habitat downstream of the Roberts Ferry Bridge is unsuitable for spawning and rearing juveniles because the channel gradient is too low to provide suitable physical habitat (i.e., few riffle habitats).
3. **Winter and Spring Juvenile Rearing**: *High flows between early-January and late-May affect juvenile survival*. It is assumed that high flows between early January and late-May affect steelhead smolt survival by:
    a. increasing rearing habitat quantity/quality as floodplain habitat increases;

b. increasing food availability from inundated floodplains,
c. improving water quality (including water temperature, contaminants, and dissolved oxygen) improves which reduces mortality from other stressors (e.g., disease, contaminates, and starvation), and
d. possibly reducing predation by Sacramento pikeminnow, black bass and striped bass.

Information Gaps

The above limiting factor analyses for Tuolumne River salmon and trout has identified key information gaps in life history trends for both species. In summary these include:

Salmon

1. The specific mechanism by which elevated winter flows result in increased in-river smolt production is unknown;
2. The most efficient flow schedule that would conserve water supplies and provide an adequate magnitude, duration, and frequency of winter and spring flows to accomplish targeted production goals is unknown;
3. Out-migrant fry contribution to escapement is unknown;
4. Water temperature impacts to juvenile production are unknown;
5. Non-flow habitat restoration that would substantially increase juvenile survival, and in-river smolt production, are unknown; and
6. Whether fall pulse flows and base flows during spawning affect the survival of out-migrating smolts is unknown.

Rainbow Trout

1. The population abundance of rainbow trout in the lower Tuolumne River.
2. The relative proportion of resident and migratory rainbow trout in the lower Tuolumne River.
3. The distribution of adult rainbow trout relative to habitat conditions in the lower Tuolumne River.
4. The effects of flow on the rainbow trout abundance and habitat availability.
5. Rainbow trout limiting factors analysis.

Management Questions and Actions

Salmon Management Questions and Actions

The following management questions are listed in order of priority of importance needed to reverse the long term declining Salmon population trend. Research should be designed to sufficiently evaluate the following management questions and adequately define effectiveness of management actions. To conduct rigorous statistical tests of these questions, it is anticipated that a sufficient number of studies be conducted. It is also anticipated that an adaptive management strategy will have to be implemented assuming that the initial results may suggest revisions management questions and/or actions.

<u>Management Question #1:</u> *Are continuously high flows between early-April and mid-June the primary determinant of smolt survival and adult recruitment in the Tuolumne River?* Management Actions: Increase the magnitude and duration of springtime pulse flows as follows, monitor the abundance of smolt out-migrants and adults, and evaluate potential cause-and-effect mechanisms:

1. Four different magnitudes of smolt out-migrant flows: 1,000 cfs, 3,000 cfs, 4,000 cfs and 5,000 cfs; and
2. Three durations of smolt out-migrant flows: 30, 45 and 60 days.

<u>Management Question #2:</u> *Do elevated floodplain inundation level flows between early-February and late-March concurrent with elevated spring time flow levels increase the number of salmon fry that survive to a smolt size in the Tuolumne River and adult recruitment in the Tuolumne River?* Floodplain inundation between La Grange and the Ruddy Gravel Mine primarily occurs between flows of 1,100 cfs and 3,100 cfs (Turlock Irrigation District and Modesto Irrigation District 2001) and so pulse flows to evaluate the benefits of floodplain inundation should be at least 2,000 cfs. Management Actions: Increase the magnitude and duration of winter flows, monitor the abundance of smolt out-migrants and adults, and evaluate potential cause-and-effect mechanisms:

1. Three durations of winter pulse flows: 15, 30 and 60 days;
2. Four different magnitudes of fry-rearing flows: 500 cfs, 2,000, 3,000 cfs and 4,000 cfs.

<u>Management Question #3:</u> *Do fry outmigrating the Tuolumne River materially contribute to adult recruitment?* Management Action: Determine fry contribution rates to adult recruitment either by otolith microchemical or microstructural analysis.

<u>Management Question #4:</u> *Do elevated fall pulse flows improve egg viability and minimize straying of early arriving adult salmon?* Management Actions:

1. Evaluate straying rates of coded-wire-tagged smolts that were released in the Tuolumne River and recovered in Central Valley adult escapement surveys relative to pulse flow releases, Delta water quality, and fall export rates;

2. Evaluate egg viability at the Merced River hatchery relative to tributary and Delta water temperatures;
3. Evaluate pre-spawn mortality surveys in the Tuolumne River relative to pulse flow releases.

Management Question #5: *Do flow and water temperature levels affect the distribution of spawners and redd superimposition rates?* Management Actions: Evaluate spawner distribution and smolt outmigration patterns by conducting intensive redd counts, rotary screw trap surveys at 7/11 and Grayson, and evaluating smoltification indices of collected juveniles.

Management Question #6: *Do physical habitat restoration projects that focus on improving floodplain habitat quantity and quality improve smolt production, and survival, in combination with elevated winter and spring time flows?* Management Actions: Design restoration projects to compare designs that inundate floodplains annually and promote and preserve riparian vegetation versus past designs that inundate floodplains primarily during wet years and promote the recruitment of spawning sized gravels and then monitor changes in the abundance of smolt out-migrants with rotary screw traps relative to the implementation of various restoration projects.

Management Question #7: *Does water temperature influence the production of salmon smolts in the Tuolumne River?* Management Action: Develop a water temperature based juvenile salmon production based simulation model to estimate juvenile production under a variety of water temperature conditions.

Management Question #8: *Do late spring ramping rates affect riparian vegetation establishment?* Management Action: Evaluate riparian plant establishment in relation to variable flow ramping schedules.

Rainbow Trout Management Questions and Actions

The following management questions are listed in order of priority of importance needed to assess the impacts of the Don Pedro FERC License and Settlement Agreement on rainbow trout. Monitoring should be designed to sufficiently evaluate the following management questions and adequately define effectiveness of management actions. It is also anticipated that an adaptive management strategy will have to be implemented assuming that the initial results may suggest revisions management questions and/or actions.

Management Question #1: What is the trend abundance of adult rainbow trout in the Tuolumne River? Management Action: Determine abundance of adult rainbow trout in the Tuolumne River.

Management Question #2: What is the abundance trend of juvenile rainbow trout in the Tuolumne River? Management Action: Determine abundance of adult rainbow trout in the Tuolumne River.

Management Question #3: What is the migratory behavior of adult *O. mykiss* in the Tuolumne River? Management action: Determine migratory behavior of adult *O. mykiss* in the Tuolumne River.

Management Question #4: What is the migratory behavior of juvenile *O. mykiss* in the Tuolumne River? Management action: Determine migratory behavior of juvenile *O. mykiss* in the Tuolumne River.

Management Question #5: What is the distribution and habitat condition in the Tuolumne River for adult O. mykiss? Management action: Determine distribution and habitat condition in the Tuolumne River for adult *O. mykiss*.

Management Question #6: What is the distribution and habitat condition in the Tuolumne River for juvenile O. mykiss? Management action: Determine distribution and habitat condition in the Tuolumne River for juvenile *O. mykiss*.

Management Question 7: What are the effects of the Tuolumne River instream flow schedule on both adult, and juvenile, rainbow trout and steelhead habitat? Management action: Determine effects of instream flow schedule upon both adult and juvenile rainbow trout, and steelhead, habitat in the Tuolumne River.

Management Question #8: What are the factors limiting both resident, and anadromous, *O. mykiss* populations in the Tuolumne River? Management action: Determine limiting factors for resident, and migratory, *O. mykiss* populations in the Tuolumne River.

Methods (Studies)

General

The following describes the study elements needed to test the key Management Questions described above. The estimated costs to implement these studies are summarized in Appendix A. To conduct rigorous statistical tests of these questions, it is anticipated that at least 10 years of studies will be needed. It is also anticipated that an adaptive management strategy will be implemented and initial results may suggest revisions in the questions or study designs.

Salmon Management Studies

Management Question #1: *Are continuously high flows between early-April and mid-June the primary determinant of smolt survival and adult recruitment in the Tuolumne River?*

> *Management Action #1*: increase the magnitude and duration of springtime pulse flows as described in the following section.
>
> *Management Action #2*: monitor the abundance smolt out-migrants. Conduct annual rotary screw trapping at Grayson from January 1 to June 15 and mark at least 2,000 juveniles for weekly calibration tests. Estimated cost: up to $175,000 annually.

Management Action #3: monitor the survival of smolt out-migrants using three methods. The first method will be to compare the abundance of juveniles passing rotary screw traps at the 7/11 site with the abundance that passes the Grayson site. Estimated cost: up to $175,000 annually for rotary screw trapping at the 7/11 site. A second method would be to artificially rear and CWT Tuolumne River juveniles for smolt survival tests under high flows. Estimated cost: approximately $125,000 annually. A third method would be to sonic tag (0.6 grams per tag) at least 100 smolts between 85 to 100 mm in length in April and another 100 smolts in May and track their movements throughout the lower Tuolumne River and San Joaquin River with 10 stationary receivers and one mobile receiver. The smallest sonic tags weight 0.6 grams each, would be surgically implanted, would function for several weeks, can be accurately detected with stationary and mobile receivers, and have no external antennae that would affect the fish's behavior. Estimated cost: approximately $225,000 for the first year and about $175,000 annually thereafter.

Management Action #4: monitor the abundance of adult salmon (escapement) by continuing the CDFG carcass surveys. Estimated cost: approximately $60,000 annually. To improve the method of segregating escapement into cohorts, continue the age analyses with the scale and otolith samples collected since the 1980s. The estimated cost to complete the analysis for the remaining Tuolumne River samples is about $100,000 and $15,000 a year thereafter to analyze newly collected samples.

Management Action #5: evaluate potential cause-and-effect mechanisms, including predation by exotic fish species, water temperature, contaminants, smoltification timing, disease, and entrainment.

> *Predation*: Conduct phased studies to determine whether predation, by native Sacramento pikeminnow (*Ptychocheilus grandis*) and introduced black bass and striped bass (*Morone saxatilis*), is reduced as water temperature declines, water quality improves, water velocity increases, and flood-related turbidity increases. The first phase of the studies would utilize either electrofishing or angling (lures that simulate the appropriately sized juvenile salmonids) to determine which fish species are preying on juvenile salmonids, when predation is occurring, and in what habitats predation is occurring. The first phase studies would be conducted over a variety of flows associated with Critical, Dry, Below-Normal, Above-Normal, and Wet water year types. If Phase I results suggest that predation is a substantial source of mortality for juvenile salmonids, then Phase II studies would estimate the total number of predators (electrofishing in early summer to minimize impacts to salmon and trout), predation rates for fry, parr, and smolts (expanded angling surveys to collect predator stomach contents), and the percentage of juveniles consumed (percentage determined by dividing numbers consumed by the calibrated screw trap estimates of total juvenile abundance). The results would help focus restoration planning on floodplain inundation or predator habitat. Estimated costs: $60,000 annually for Phase I electrofishing studies or $30,000 annually for Phase I angling studies conducted during the April 1 to June 15 smolt outmigration period; Phase I studies should be conducted for at

least three years. Estimated Phase II costs would range from $250,000 to $500,000 annually for a minimum of three years.

Water Temperature, Food Availability Contaminants, Smoltification Timing, And Disease: At weekly intervals from March 1 through June 15, collect a total of about 360 juvenile salmon annually over the next ten years with rotary screw traps and seines for physiological, histological, and disease analyses. The US Fish And Wildlife Service, California - Nevada Fish Health Center will determine the incidence and severity of infection for external and internal parasites, including Tetracapsuloides bryosalmonae (detected in 2001 and causes Proliferative Kidney Disease), systemic viral and bacterial infections (including R. salmoninarum that causes Bacterial kidney disease in salmonids) in juvenile Chinook salmon (50 - > 80 mm FL, March – June). They will also determine the energy reserves of juvenile Chinook salmon (50 - > 80 mm FL, March – June). Specific measurements to include whole body content of protein, triglyceride, and percent lipid. And they will monitor gill Na-K- Adenosine Triphosphatase activity to track smoltification timing and examine sections of liver and kidney for abnormalities associated with toxic insult. The estimated cost for the California - Nevada Fish Health Center to conduct these studies is $60,000 annually; this assumes that other researchers will collect, prepare, and ship the specimens to the lab at Anderson, California.

If histological studies show signs of toxic insult (i.e., adverse impacts from pesticides or other contaminants), then a bioassay lab should be established on the Tuolumne River. Dr. Don Weston, UC Berkeley, recommends that a stream-side bioassay system could be used to create three treatment levels: unfiltered water, sediment-free water, and dissolved organic free water, in which juvenile salmon would be reared. This design would determine if the causative agent of the developmental defects is in the water, and if so, if it is particle-bound or dissolved. It may also be important to include prey organisms of the juvenile salmon, thus getting information on toxicity to prey and indirect food limitation impacts. The study metrics would include estimates of direct mortality as well as sublethal effects determined by histology studies. Dr. Weston estimated that the cost to conduct the bioassay tests would be about $160,000 annually, the costs for the histological studies would be about $25,000 annually, and the cost to construct a stream-side lab would be about $50,000.

If lipid content analysis indicates that food availability for juvenile fish may be a limiting factor, studies should be conducted to evaluate whether food resources are primarily aquatic or terrestrial and to compare allochthonous production, autochthonous production, and production from within New Don Pedro reservoir (planktonic). Food resources should be evaluated by examining the gut contents of at least 100 juveniles each month from January 1 through June 1. At a minimum, the studies would be conducted during dry years (base flows only during rearing) and wet years (immediately following floodplain inundation between February 1 and April 15) to compare allochthonous production with autochthonous production. Allochthonous production (e.g., invertebrates and organic matter) would be measured directly using drift-type nets placed at the downstream end of floodplains and in small tributaries. Autochthonous production should evaluate the importance of salmon carcasses using isotope analyses. The costs for these studies have not been estimated.

Entrainment: Monitor small fyke nets within diversion canals during peak diversion periods within the rearing and smolt out-migration periods. This task depends on obtaining landowner permission to conduct these studies. Such permission is typically granted only when the agencies guarantee the landowner that funds will be provided to fully screen the diversion if observed entrainment rates require screening. The implementation and costs of this task have not been determined.

Management Question #2: *Do elevated floodplain inundation level flows between early-February and late-March concurrent with elevated spring time flow levels increase the number of salmon fry that survive to a smolt size in the Tuolumne River and adult recruitment in the Tuolumne River?* Floodplain inundation between La Grange and the Ruddy Gravel Mine primarily occurs between flows of 1,100 cfs and 3,100 cfs (Turlock Irrigation District and Modesto Irrigation District 2001) and so pulse flows to evaluate the benefits of floodplain inundation should be at least 2,000 cfs.

Management Action #1: Increase the magnitude and duration of winter flows.

Management Action #2: Monitor the abundance of smolt out-migrants and adults. Utilize the same studies for Management Actions #2, #3, and #4 for Management Question #1. No additional costs.

Management Action #3: Evaluate potential cause-and-effect mechanisms. Utilize the same studies for Management Action #5 for Management Question #1, except conduct Phase I Predation studies during the rearing period, February - March. Estimated costs: $60,000 annually for Phase I electrofishing studies or $30,000 annually for Phase I angling studies conducted during the February 1 to March 31 rearing period; Phase I studies should be conducted for at least three years. There would be no additional costs for Phase II studies.

Management Question #3: *Do fry outmigrating the Tuolumne River materially contribute to adult recruitment?*

Management Action: Determine fry contribution rates to adult recruitment either by otolith microchemical or microstructural analysis. Studies would be conducted in a phased approach. The initial pilot studies will evaluate whether microchemical or microstructural analysis of adult otoliths can distinguish between juveniles that reared in the Tuolumne River and those that reared in the Delta. The estimated cost to conduct the pilot microchemical and microstructural analyses would be about $100,000 for 100 otolith samples.

Management Question #4: *Do elevated fall pulse flows improve egg viability and minimize straying of early arriving adult salmon?* Management Actions:

Management Action #1: Evaluate straying rates of coded-wire-tagged smolts that were released in the Tuolumne River and recovered in Central Valley adult escapement surveys relative to pulse flow releases, Delta water quality, and fall export rates. The AFRP has funded Stillwater Sciences to conduct this analysis with the existing CWT recovery data through fall 2005.

Management Action #2: Evaluate egg viability at the Merced River hatchery relative to tributary and Delta water temperatures. This analysis could be done with existing data for an estimated cost of $25,000 to $50,000.

Management Action #3: Evaluate pre-spawn mortality surveys in the Tuolumne River relative to pulse flow releases. This task would require the CDFG carcass survey crews to collect the eggs from a sample of at least 100 adult female carcasses and then count the eggs following the surveys. Relationships would be evaluated between the timing and occurrence of fall pulse flows and the number of eggs retained per female. Estimated cost: $10,000 to $20,000 annually.

Management Question #5: *Do flow and water temperature levels affect the distribution of spawners and redd superimposition rates?*

Management Actions: Evaluate spawner distribution and smolt outmigration patterns by conducting intensive redd counts, rotary screw trap surveys at 7/11 and Grayson, and evaluating smoltification indices of collected juveniles. The rotary screw traps surveys and evaluations of smoltification indices would be done for Management Question #1. The intensive redd counts would require a foot survey of all spawning habitats between La Grange and Waterford during mid-November for at least three years. The estimated cost for the intensive redd counts would range between $20,000 and $40,000 annually. It will also be necessary to continue monitoring water temperatures between La Grange and Waterford with thermographs.

Management Question #6: *Do physical habitat restoration projects that focus on improving floodplain habitat quantity and quality improve smolt production, and survival, in combination with elevated winter and spring time flows?*

Management Actions: Design restoration projects to compare designs that inundate floodplains annually and promote and preserve riparian vegetation versus past designs that inundate floodplains primarily during wet years and promote the recruitment of spawning sized gravels and then monitor changes in the abundance of smolt out-migrants with rotary screw traps relative to the implementation of various restoration projects. The estimated cost of designing new restoration projects has not been determined. Evaluations of projects designed to provide or enhance spawning habitat should measure the survival of newly fertilized eggs in incubation chambers rather than rely on indirect measures of dissolved oxygen and gravel permeability. Egg survival studies should be conducted over three years to account for variation in turbid storm runoff, egg viability in hatchery fish, and flood scouring flows. The estimated cost of egg survival studies, which only measure egg survival without monitoring environmental parameters, would be about $50,000 annually. The rotary screw traps surveys would be conducted for Management Question #1.

Management Question #7: *Does water temperature influence the production of salmon smolts in the Tuolumne River?*

Management Action: Develop a water temperature based juvenile salmon production based simulation model to estimate juvenile production under a variety of water temperature conditions. The Calfed Bay Delta Authority has already funded this action. However, it will be necessary to continue monitoring water temperatures with multiple thermographs located throughout the lower Tuolumne River for the duration of these studies.

Management Question #8: *Do late spring ramping rates affect riparian vegetation establishment?*

Management Action: Evaluate riparian plant establishment in relation to variable flow ramping schedules. This action would be implemented under existing studies to monitor restoration projects.

Rainbow Trout Management Studies

Management Question #1: What is the trend abundance of adult rainbow trout in the Tuolumne River?

Pipal (2005) identified 6 Central Valley sampling programs specifically designed for estimating the population size of the anadromous component of *Oncorhynchus mykiss* (*O. mykiss*). These sampling programs were located in the upper Sacramento River and in Battle, Mill, and Deer Creeks and consisted of obtaining passage estimates at weirs and dams and in addition utilized fyke nets, and miscellaneous traps. Two widely used methods for estimating stream fish abundance are seining and electrofishing. These methods have commonly been used across North America, including the Tuolumne River in effort to estimate abundance (Hankin and Reeves 1988, Reynolds, J.B. 1996, Thompson 2003). In addition, electrofishing has been used to track the relative abundance of resident fishes in large bodies of water such as the Sacramento-San Joaquin Delta (Michniuk and Silver 2002, Michniuk 2003). Redd surveys also are another potential method used to estimate populations of *O. mykiss*; however, these methods have proven difficult in the Tuolumne River as spawning often occurs in deep turbulent water, making visual observation difficult. Hook and line fishing completed on the Tuolumne River in conjunction with professional fishing guides in recent years has yielded samples for anadromous *O. mykiss* analysis. Note this method is dependent on scarce fishing expertise.

Management Action: Electrofishing, snorkeling, and other recapture methods such as hook and line are recommended to estimate the abundance of *O. mykiss* on the lower Tuolumne for several reasons: they both target anadromous and resident *O. mykiss*, they take advantage of existing efforts and resources keeping costs down, are widely accepted methods in the literature, and appear to have the most feasibility.

(1) Electrofishing – Intensive sampling for adult *O. mykiss* (excluding YOY) approximately every 5-10 days between February and April with a boat between river miles 30 and 52. A total of four, one mile segments with representative stream habitat types should be sampled. "Catch per unit effort by electrofishing is a useful, easily obtained index to the abundance of the populations of many species;" however, estimates of absolute abundance can be biased (Reynolds 1996). Catch per unit effort in a variety of habitat types should be calculated. Methods also should be developed to capture and tag adult *O. mykiss* for recapture purposes and for abundance estimation. Marking estimates visible during snorkeling are encouraged. Depending on the observed biases of using electrofishing for mark recapture purposes, and whether or not correction factors can be utilized, other measures may be needed for tagging and or recovery (such as hook and line). The use of photo mark recapture should also be evaluated.

Data Analysis/Reporting/Costs: Population estimates for the lower Tuolumne River should be calculated using recapture data from electrofishing, hook and line, or other methods as appropriate. A technical report should be produced, reviewed, and approved by fisheries agencies. Estimated cost for this assessment is $130,000 per year (based on 30 days of electrofishing at $2,000 per day, $30,000 for additional recovery efforts, and $40,00 for analysis and report writing).

(2) Snorkeling – Monthly at selected sites from La Grange Dam, downstream to RM 30. A total of three snorkelers should be utilized: one on each bank of the river, and one in the center. Snorkelers should float downstream noting adult and juvenile *O. mykiss* (for acceptable methods, see California Department of Water Resources (2003).

Data Analysis/Reporting/Costs: If adult *O. mykiss* are sufficiently marked, and can be identified using snorkeling methods, additional populations estimates should be possible. In addition, the population can be estimated using snorkeling techniques without the use of recapture methods. A technical report should be produced, reviewed, and approved by fisheries agencies. Estimated costs for this effort are estimated at $52,000 per year (12 days at $1,000 per day, and $40,000 per year for analysis and report writing).

<u>Management Question #2:</u> What is the abundance trend of juvenile rainbow trout in the Tuolumne River?

As Pipal (2005) indicates, most juvenile steelhead data on migration periods and relative abundance is collected from rotary screw traps in the Central Valley. For example, 7 separate steelhead recovery efforts are currently implemented with rotary screw traps in the Central Valley (Pipal 2005). Other sampling devices used to calculate relative abundance include seines, fyke nets, and trawls. Habitat in the lower Tuolumne River prohibits trawling, and rotary screw traps scarcely capture juvenile steelhead/rainbow trout. The best choices for monitoring the relative abundance of steelhead/rainbow trout is snorkeling. Past snorkeling in the Tuolumne River for Chinook salmon has reported *O. mykiss* observations and with some adjustment, this sampling program could significantly improve steelhead/resident rainbow trout abundance estimates.

Management Action: Snorkeling is recommended to estimate the abundance of *O. mykiss* on the Lower Tuolumne as it takes advantage of existing efforts and resources keeping costs down, is a widely accepted method in the literature, and appear to have the most feasibility. See adult snorkeling methods.

<u>Management Question #3:</u> What is the migratory behavior of adult *O. mykiss* in the Tuolumne River?

The Anadromous Fish Restoration Program (AFRP) funded the CDFG to determine the distribution and relationship of resident and anadromous Central Valley *O. mykiss* (AFRP identification code 2003-05). Otoliths of juvenile trout from many Central Valley watersheds have been and continue to be analyzed to determine parental life history strategy (anadromous or resident). The determination will be based on examination of the ratio of strontium to calcium within the otolith. Anadromy has been documented from the Calaveras, Merced and San Joaquin Rivers. A variety of methods have been reported in the literature to determine the presence of anadromy including microchemistry and microstructure analysis of otoliths and scales. Most prominent appears to be an analysis of the relationship of the strontium-to-calcium ratios and salinity, thus proof of anadromy.

Management Action: All adult *O. mykiss* encountered during authorized activities should have representative scale samples taken and archived for future anadromy determination. In addition, 10% of adult captures should be retained for otolith analysis (as well as all mortalities). Chain of custody and otolith and scale analysis should be completed by CDFG. For a review of methods see Zimmerman (2005).

Otolith microchemistry and scale microstructure analysis - Chemical tests of otoliths for anadromy should be completed using the strontium-to-calcium ratio. Scale microstructure analysis for anadromy should be completed and validated with otolith analysis.

Data Analysis/Reporting/Costs: A technical report should be produced, reviewed, and approved by fisheries agencies. Estimated costs are $55,000 per year (based on the processing of 10 otoliths at $1,000 each and 100 at $500 each, and $40,000 for analysis and technical report writing).

<u>*Management Question #4:*</u> What is the migratory behavior of juvenile *O. mykiss* in the Tuolumne River?

Pipal (2005) and the Interagency Ecological Program (IEP, 2005) reviewed the various juvenile salmonid sampling efforts in the Central Valley. Monitoring programs with the specific goal of determining the temporal patterns of steelhead smolts are dominated by the use of rotary screw traps; however, seining, snorkeling, electrofishing, enclosure nets, and trawling also are used. Based on the date of capture, size of the *O. mykiss*, and the physiological state of the fish, the anadromous presence can be established.

Management Action: To take advantage of existing and recommended to be expanded sampling for Chinook salmon, rotary screw traps are recommended. Though catchability of smolt *O. mykiss* is low in rotary screw traps, they nevertheless can be used to document the presence of smolts captured incidentally. Though electrofishing is most efficient at capturing adults, incidentally captured juvenile *O. mykiss* should be recorded. Lastly, seining and snorkeling will encounter juvenile *O. mykiss*. All dead *O. mykiss* encountered during authorized activities should be turned over to CDFG for otolith and scale analysis. In addition, to measure the parr-smolt transformation and increase in seawater tolerance, thus anadromoy, gill ATPase studies are recommended (evidence of smoltification is found with an increase in gill sodium-potassium-activated adenosine triphosphatase (Na+, K+,-ATPase). The measurement of gill Na+, K+,-ATPase activity has been utilized extensively to monitor smolt physiology.

(1) Rotary Screw Trap Sampling- Rotary screw trap sampling is recommended for Chinook salmon at two locations on the Tuolumne River; upstream and downstream, and studies and incidental captures of *O. mykiss* should recorded. Ten percent of the capture of *O. mykiss* should be sacrificed for gill ATPase studies.

    Data Analysis/Reporting/Costs: Total catch of *O. mykiss*, fork length, date of capture, smolt level (1-5), and effort should be reported. Costs are covered under the Chinook salmon monitoring studies. Some additional costs may be needed for the analysis and summary. A technical report should be produced, reviewed, and approved by fisheries agencies.

(2) Electrofishing- Electrofishing is recommended to document the abundance of *O. mykiss* for a three-month period in the winter (February to April); however, additional sampling is needed monthly at a variety of sites between river mile 30 and 52.

Data Analysis/Reporting/Costs: Total catch of *O. mykiss*, fork length, date of capture, smolt level (1-5), and effort should be reported at all sample sites. Ten percent of the capture of *O. mykiss* should be sacrificed for gill ATPase studies. Costs are estimated at $78,000 per year (10 ATPase samples at $2,000 each, 9 electrofishing days at $2,000 per day, and $40,000 for analysis and report writing). A technical report should be produced, reviewed, and approved by fisheries agencies.

(3) Snorkeling- Snorkeling is recommended monthly between La Grange Dam and RM 30 (see above). Information on juvenile *O. mykiss* should be collected.

Data Analysis/Reporting/Costs: Total observations of *O. mykiss*, estimated fork length, date of observance, smolt level (1-5), and effort should be reported at snorkel sites. Costs are included above in snorkeling for abundance (#1). A technical report should be produced, reviewed, and approved by fisheries agencies.

Management Question #5: What is the distribution and habitat condition in the Tuolumne River for adult O. mykiss?

Management Action: The two most commonly used methods to determine the distribution of adult salmonids relative to habitat conditions in the Central Valley are electrofishing and snorkeling (Pipal 2005). These efforts have already been recommended above, and the results of surveys (#1, #2) in combination with habitat analysis can be used to distinguish the distribution of *O. mykiss* and their affinity for certain habitat types. In addition, redd surveys are needed.

(1) Electrofishing and Snorkeling- Utilizing recommended electrofishing and snorkeling elements above and collected habitat information, the affinity of adult *O. mykiss* for a variety of habitat types in the Tuolumne River should be established. This information could also be used to assess the potential impacts of restoration on *O. mykiss* habitat.

Data Analysis/Reporting/Costs: Additional costs are negligible, as they are primarily included in prior elements.

(2) Redd Surveys- The appropriate *O. mykiss* redd survey techniques should be developed on the Tuolumne River as done in other rivers of the Central Valley (American River, Battle Creek, Clear Creek, Calaveras River, *etc*.). Redd

survey effort should be done weekly between December and April between Bobcat Flat and La Grange Dam.

Data Analysis/Reporting/Costs: Documented survey methods and results are required and this task must be operated adaptively. Costs are estimated $80,000 per year ($8,000 per week for 5 months, and $40,000 for analysis and report writing).

Management Question #6: What is the distribution and habitat condition in the Tuolumne River for juvenile O. mykiss?

Management action: Snorkeling is recommended in #1 and #2 above should be utilized in this respect to document specific habitat affinities of juvenile *O. mykiss*, including restored sites. Acceptable methods are found in California Department of Water Resources (2003).

(1) Snorkeling- Monthly at selected sites from La Grange Dam, downstream to RM 30. Special emphasis should be placed on restored sites. As the case for adults, the affinity of adult *O. mykiss* for a variety of habitat types in the Tuolumne River should be established.

Data Analysis/Reporting/Costs: A technical report should be produced, reviewed, and approved by fisheries agencies. Estimated costs for this effort are estimated at $40,000 per year for analysis and report writing (sampling costs covered above).

Management Question 7: What are the effects of the Tuolumne River instream flow schedule on both adult, and juvenile, rainbow trout and steelhead habitat?

Management action: The Instream Flow Incremental Methodology (IFIM) is a conceptual framework for presenting decision makers with a series of management options, and their expected consequences, in order that decisions can be made, or negotiations begun, from an informed position. Although physical habitat simulation is the most commonly applied component of PHABSIM, an IFIM study may also include water quality, temperature and legal / institutional analysis, time series analysis, effective habitat analysis and / or population modeling. Population studies, such as those above that relate flows to population levels and response, and validate the IFIM work also are important. Recent radio-telemetry work along the Pacific Coast offers a lot of promise and should be investigated.

(1) IFIM- IFIM modeling should be developed, incorporating flow and physical parameters such as temperature.

Data Analysis/Reporting/Costs: A rough cost estimate for the construction and calibration model is $750,000.

(2) Radio-telemetry- Radio-telemetry studies should be completed to evaluate and validate the IFIM recommendations. Radio tags should be inserted in adult and juvenile captured fish *O. mykiss* and monitored with vessel, car, or airplane. Specimen movement relative to flow changes, temperature conditions, and habitat features should be noted.

Data Analysis/Reporting/Costs: The results of the telemetry work should evaluate the IFIM work, and provide information on the impacts of flow and non-flow operations on *O. mykiss*. Costs for this effort are estimates at $100,000 per year for three years.

<u>Management Question #8: What are the factors limiting both resident, and anadromous, O. mykiss populations in the Tuolumne River?</u>

Management action. Conduct a limiting factors analysis. A synthesis of historic and new information (from above studies) should be utilized to evaluate the relative impacts of the following on *O. mykiss* in the lower Tuolumne River: contaminants, food limitation, disease, predation, parasites, temperatures, habitat quality, flows, recreational fishing, poaching, and other potential stressors.

Data Analysis/Reporting/Costs: Costs are estimated at $150,000 for this task.

Experimental Flow Schedules

<u>Experimental Flow Schedules</u>
To test the underlying hypotheses of the Agencies' Salmon Model and help recover the Tuolumne River salmonid populations, the Agencies recommend that a new experimental flow schedule should be implemented immediately. Using the multiple regression correlation between rearing flows and duration, and smolt flow and duration, a simple adult recruitment model was used to develop the following flow schedule (Table 6) which the model suggests would increase fall-run Chinook salmon in the Tuolumne River.

For the experimental flow schedule, base flows are assumed to be of secondary importance. Therefore moderate levels are recommended to provide a minimal amount of habitat during most years for spawning, egg incubation, and summer rearing based on instream flow studies conducted by EA Engineering, Science, and Technology (Turlock Irrigation District and Modesto Irrigation District 1991c, EA 1993). The recommended base flows are increased during Wet years to provide the means to evaluate the effects of base flows on Salmon and *O. mykiss* distribution. A spawning base flow of 200 cfs is recommended from October 1 through March 31 during all but Wet years; whereas spawning base flows of 300 cfs are recommended during wet years. A base flow of 400 cfs is recommended during April in Critical and Dry years. Summer base flows of 150 cfs are recommended during all but Wet years to provide a minimum of 8 miles of habitat with water temperatures below 65° Fahrenheit for rearing *O. mykiss*; whereas, a summer base flow of 250 cfs is recommended during Wet years to provide a minimum of 13 miles of habitat. A 10-day, mid-October pulse flow of 1,500 cfs is recommended for all water year types to minimize the rate that Tuolumne River fish might stray to other watersheds (Mesick 2001). To help determine the optimum rate for ramping down spring flows to ensure the establishment of riparian seedlings, spring flow ramp down rates of 100 cfs/day, 200 cfs/day, and 300 cfs/day should be implemented in different years to permit seedling survival studies. The determination of the appropriate ramp down rate could be made by the Tuolumne River Technical Advisory Committee in each year depending on the availability of water and the need to conduct the study.

Table 6. Recommended experimental flow schedule intended to test the importance of the magnitude and duration of juvenile rearing flows (Rearing Q) during the February and March period and smolt out-migration flows (Smolt Q) during the April to mid-June period.

Proposed Flow Schedule					
Water Year Type	Rearing Q (cfs)	Rearing Duration (days)	Smolt Q (cfs)	Smolt Duration (days)	Expected Production Improvement (%)
Very Wet	4000	60	5,000	60	TBD
Wet	3000	60	4,000	60	TBD
Above Normal	3000	30	3000	45	TBD
Below Normal	2000	30	3000	45	TBD
Dry	2000	15	2000	30	TBD
Critical	500	15	1000	30	TBD

This approach assumes that a large increase in spring flow will be needed to detect a statistically significant change in adult recruitment. It also assumes that a large increase in fishery flows could be achieved by aggressively managing the storage in New Don Pedro Reservoir (NDP)[12]. Since 1980, storage in NDP has been maximized (Figure 23) to primarily meet water supply and power generation demands, which results in flood control releases in January and February and low flows between April and mid-June during Below Normal and drier years that do not protect smolt out-migrants. By increasing the amount of water released during the smolt out-migration period, NDP storage would be reduced and more inflow could be captured to improve both flood control and fishery flows.

It is believed that sufficient storage (water assets) exists to accommodate the proposed flow schedule without impacting water supply reliability. The average total annual release[13] from La Grange Dam from 1970 through 2004 was 707 Thousand Acre-feet (TAF; Figure 24), much of which was released for flood control considering that the current average FERC minimum flow schedule annual amount is 185 TAF. The agencies assume that if fish flow releases were increased from a mean of 185 TAF required under the FSA to a mean annual total of about 600 TAF, the salmon population would increase

[12] Modified water year type based instream flow schedules would be met through re-operation of currently available water supply (i.e. re-operation of New Don Pedro to diminish frequency, magnitude, and duration of flood control releases without diminishing diversion supply).
[13] Annual = Water year type calendar beginning on October 1 and ending on September 30.

and flood control would be improved without reducing the irrigation districts' water supply. To protect water supply for agricultural demand, hydropower generation, ad fish production, the Agencies expect that "triggers" (such as minimum NDP storage, and/or frequency of water year type—third consecutive critical dry year etc), in addition to water year type, would be identified and implemented in accordance with the proposed schedules that would in essence, create a, yet to be identified, an adaptive management driven instream fish production schedule that differs from those presented below. It would be expected that the adaptive management schedules would be the exception, rather than the "norm." The Agencies recommend conducting a NDP operational study to identify an experimental instream flow schedule that would not reduce water supply reliability, minimize impacts to hydro-power generation, improve flood control operations, and provide the basis to test hypotheses regarding salmonid production. Preliminary revised minimum instream flow schedules are identified in Figures 25-30.

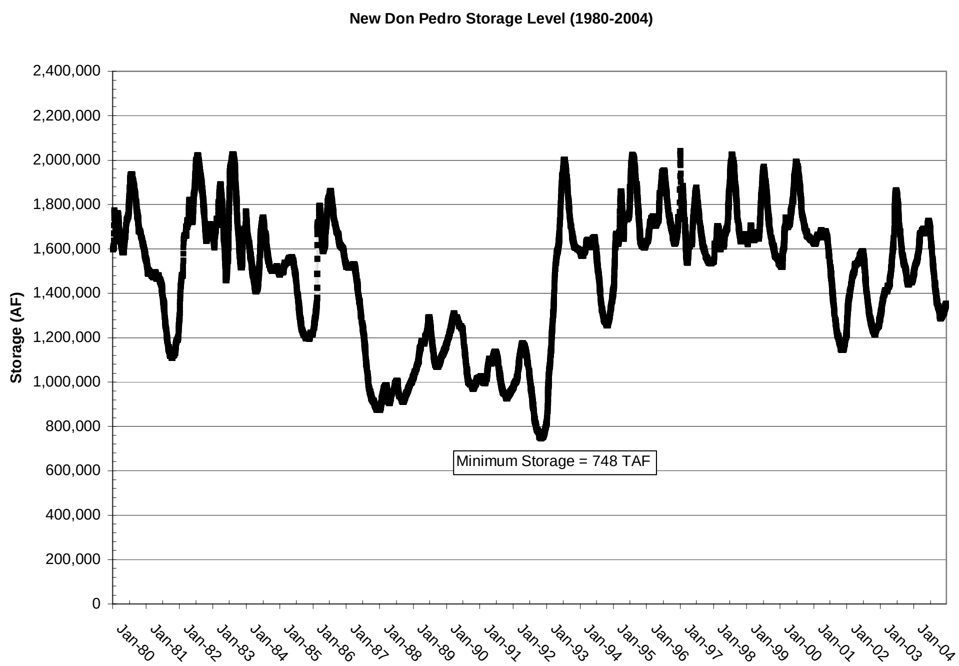

Figure 23. New Don Pedro Storage from 1980 to 2004.

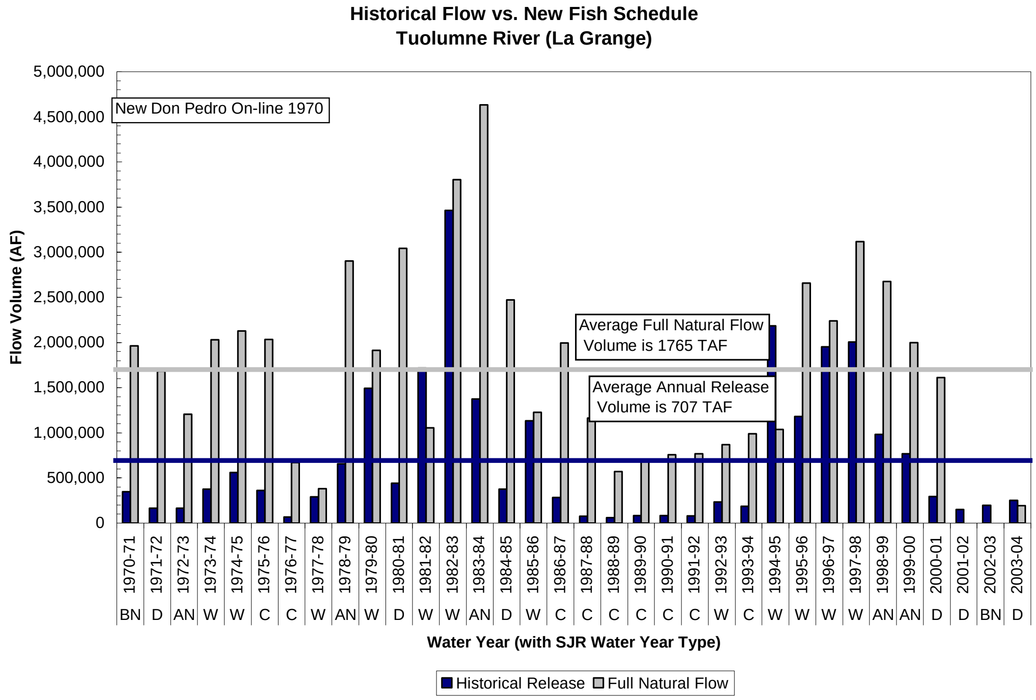

Figure 24. Tuolumne River Historical Annual Release Volume from 1980 to 2004.

Revised Flow Schedules

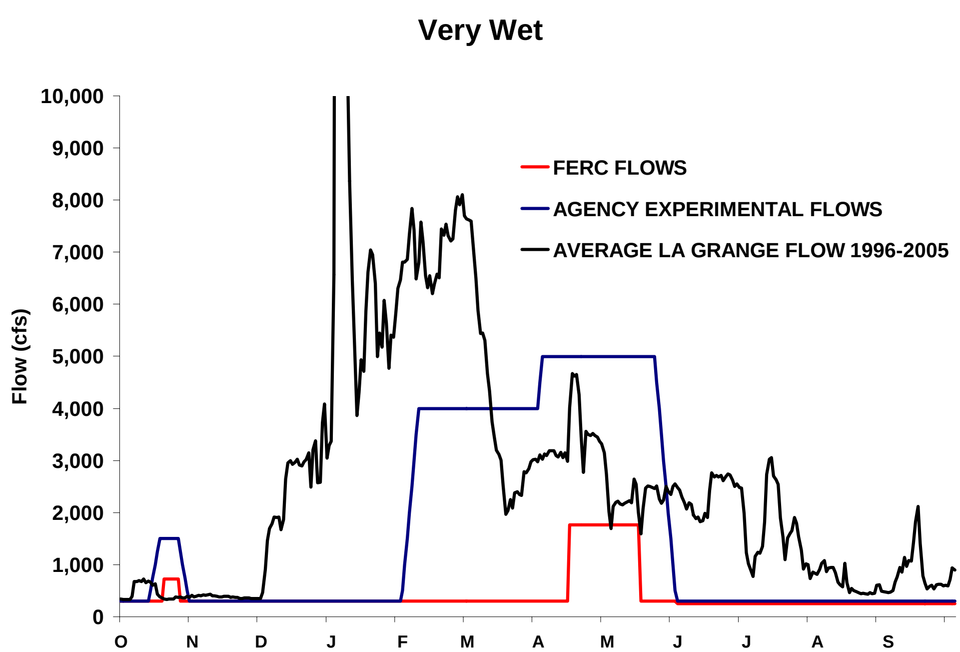

Figure 25. The Tuolumne River flow schedule presented in Table 2 for a Maximum Wet year as well as the current FERC minimum flow requirements and the mean estimated flow at La Grange between 1996 and 2005. Spring flows are ramped down 200 cfs/day. The total volume of the experimental flows and gauged La Grange flows are 1,174.016 and 1,979,743 AF, respectively.

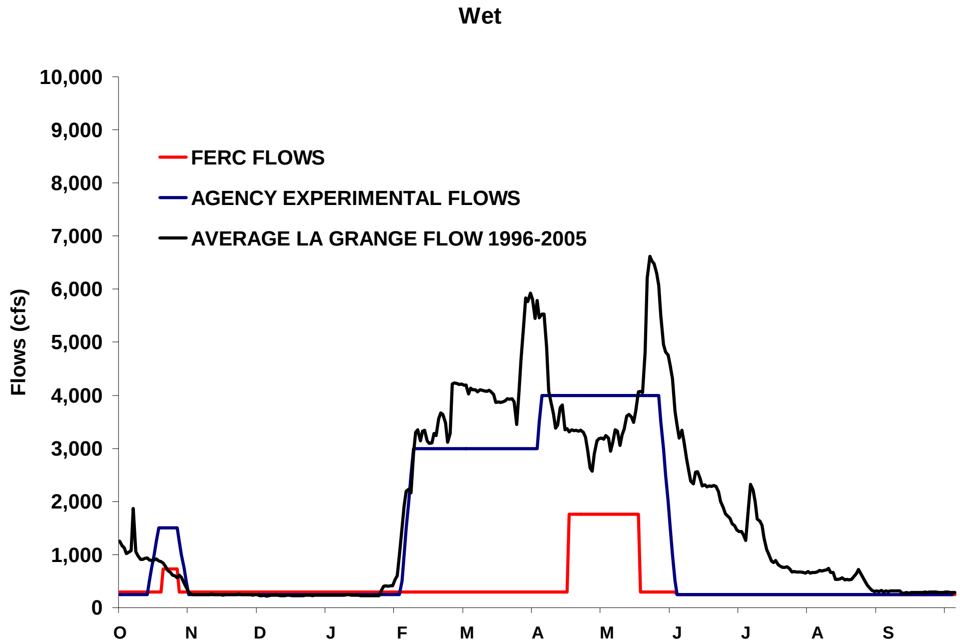

Figure 26. The Tuolumne River flow schedule presented in Table 2 for a Normal Wet year as well as the current FERC minimum flow requirements and the mean estimated flow at La Grange between 1996 and 2005. Spring flows are ramped down 200 cfs/day. The total volume of the experimental flows and gauged La Grange flows are 943,140 and 1,282,088 AF, respectively.

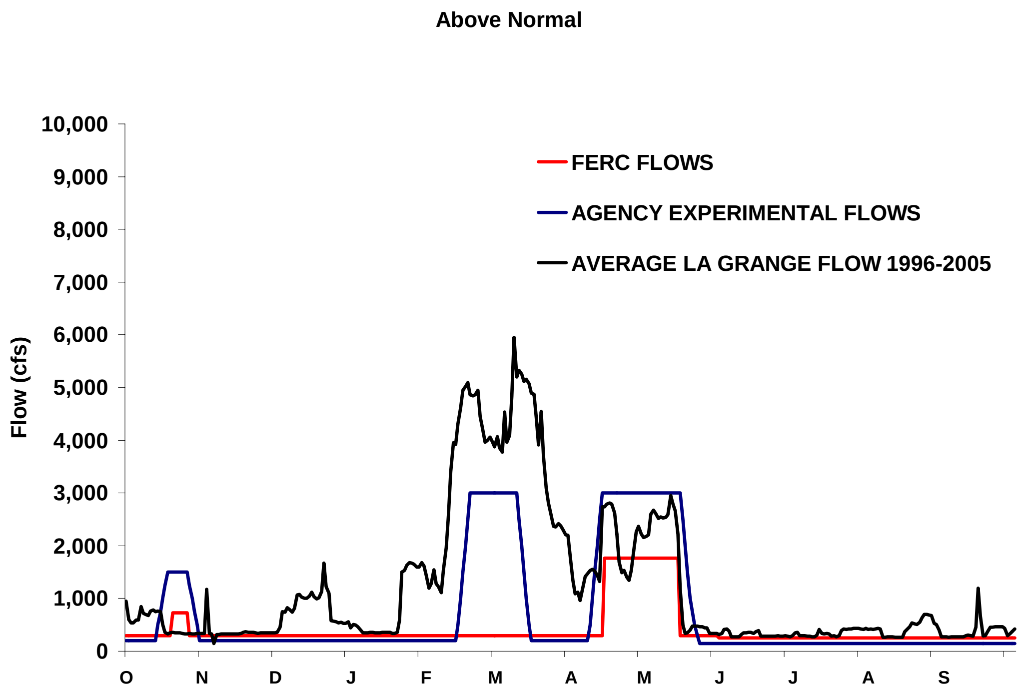

Figure 27. The Tuolumne River flow schedule presented in Table 2 for an Above Normal year as well as the current FERC minimum flow requirements and the mean estimated flow at La Grange between 1996 and 2005. The total volume of the experimental flows and gauged La Grange flows are 513,025 and 867,707 AF, respectively.

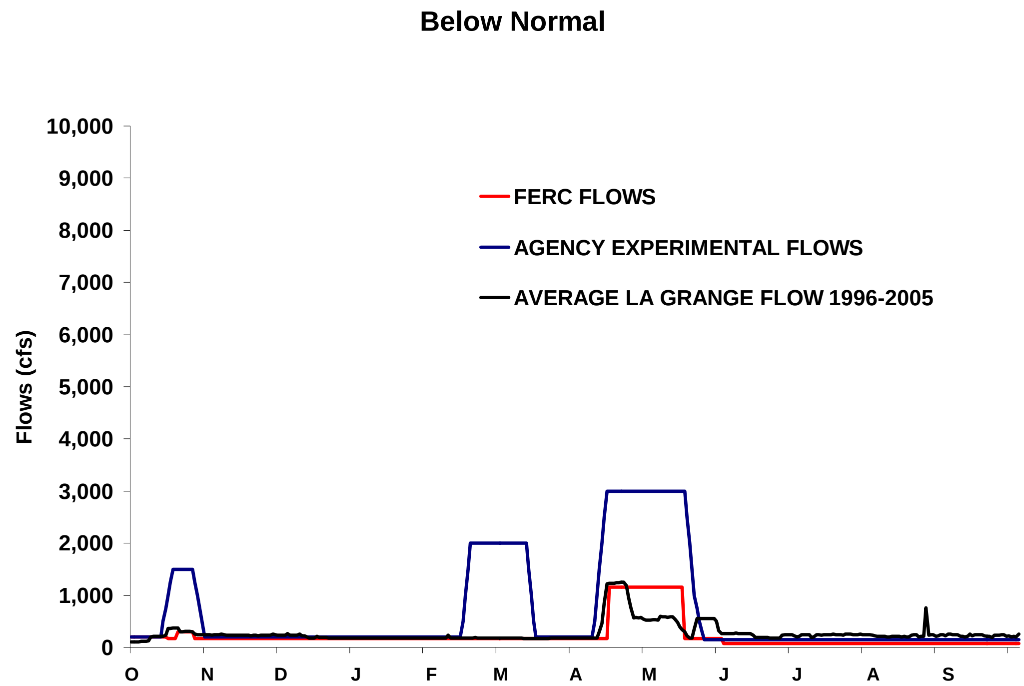

Figure 28. The Tuolumne River flow schedule presented in Table 2 for a Below Normal year as well as the current FERC minimum flow requirements and the mean estimated flow at La Grange between 1996 and 2005. The total volume of the experimental flows and gauged La Grange flows are 471,372 and 198,871 AF, respectively.

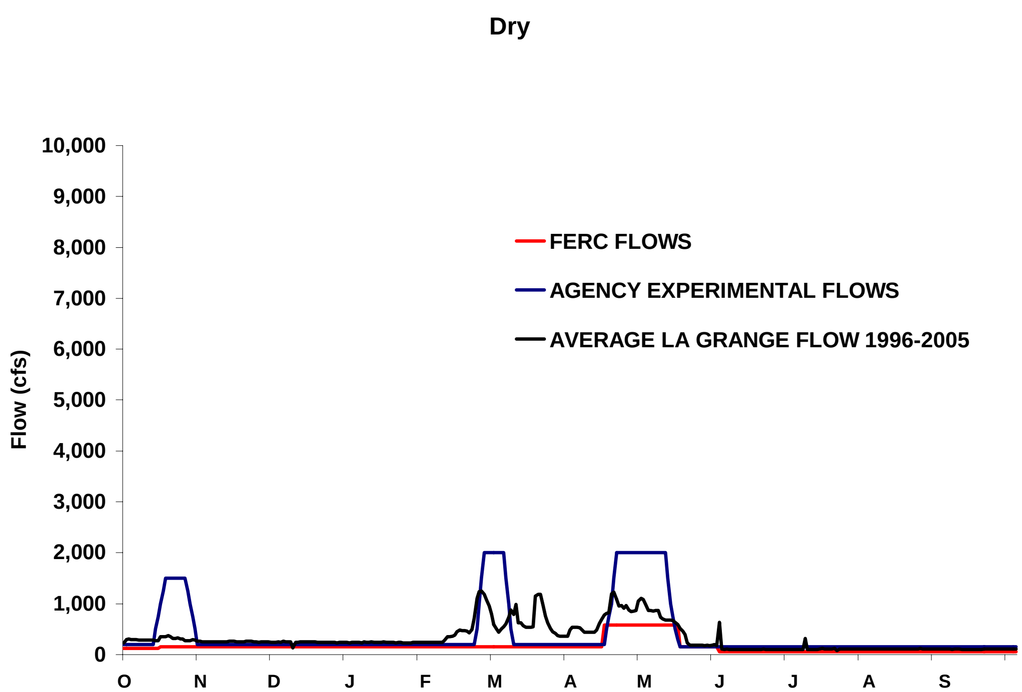

Figure 29. The Tuolumne River flow schedule presented in Table 2 for a Dry year as well as the current FERC minimum flow requirements and the mean estimated flow at La Grange between 1996 and 2005. The total volume of the experimental flows and gauged La Grange flows are 293,554 and 234,430 AF, respectively.

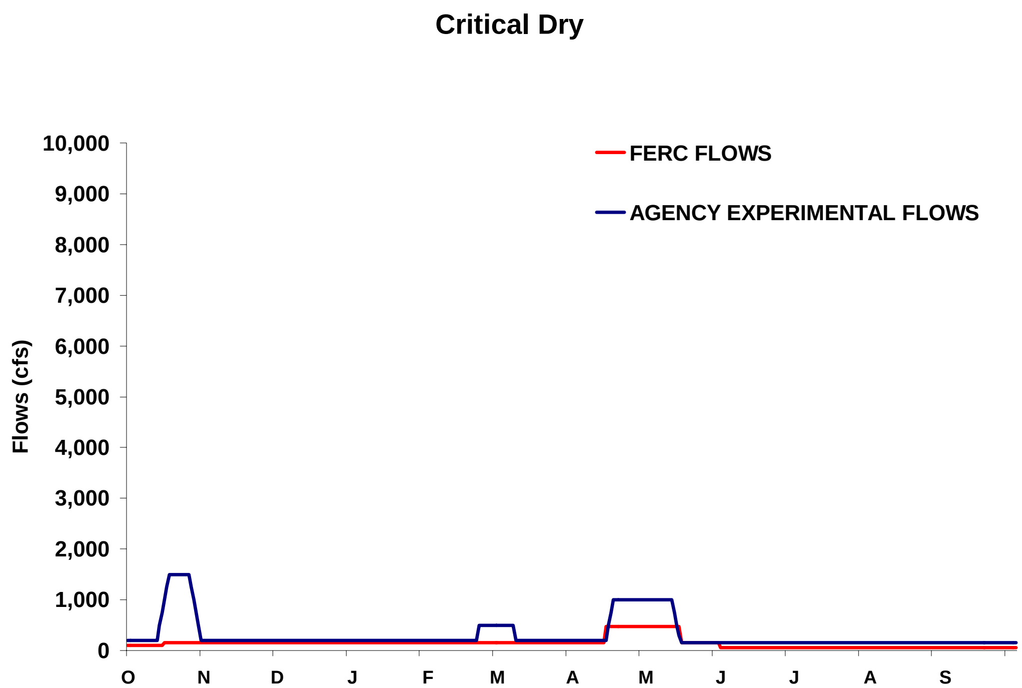

Figure 30. The Tuolumne River flow schedule presented in Table 2 for a Critical year as well as the current FERC minimum flow requirements. The total volume of the experimental flows is 217,139 AF. No Critical water years occurred from 1996 to 2006.

Conclusions/Discussion/Recommendations

The Agencies developed this draft management conceptual model for the Tuolumne River based on existing Chinook salmon population trends relative to flow and other habitat conditions in the river, Delta, and ocean. The result of these trend analyses provides a likely explanation of how ecosystem processes, including flow management and restoration, affect the production of adult Chinook salmon and adult rainbow trout in the Tuolumne River. However, trend analyses do not provide proof of cause-and-effect mechanisms and therefore they primarily help identify key management questions regarding ecosystem effects on salmonid populations. The Agencies refer to this set of management assumptions, management questions, management actions, and monitoring studies as a management conceptual model. The Agencies envision that this conceptual model and corresponding sets of management actions would be tested by monitoring the response of the salmonid populations to manipulations of flow and physical habitat and to refine cause-and-effect mechanisms. Another objective of the management conceptual model is to begin collecting the population trend data necessary to assess the status of the rainbow trout population in the Tuolumne River and refine the development of the conceptual model.

The primary difference between this management conceptual model and the existing conceptual model developed by the Turlock and Modesto Irrigation districts is that the Agencies believe that the production of adult salmon in the Tuolumne River is strongly dependent on an extended period of flow, presumably from early February through mid

June, which affects both rearing habitat and production of smolt out-migrants in the Tuolumne River. Although the existing model considers that smolt survival through the Delta is an important factor, adult salmon recruitment is primarily dependent upon flow related juvenile production in the Tuolumne River. Instead of focusing upon in-river flow levels, the existing model focuses on degraded spawning habitat and predation to be the primary factors limiting the salmon population in the Tuolumne River (Turlock Irrigation District and Modesto Irrigation District 2005).

Based upon information presented in this paper and referenced in the scientific literature the Agencies believe that (not listed in order of priority):

1. It appears conditions in the Tuolumne River have caused the decline in salmon abundance.
2. The recent management emphasis on non-flow physical habitat restoration, in-lieu of increasing instream flows, to accomplish major salmon production gains appears to need re-examination. It appears a detectable increase in adult recruitment in the Tuolumne River as a result of emphasizing non-flow physical habitat has not occurred. In the both the Stanislaus and Tuolumne Rivers, the survival of juveniles migrating between upper and lower rotary screw trap sites in response to different hydrographs suggests that flows in February and March have a significant effect upon in-river juvenile survival and the production of smolt-sized outmigrants. Therefore, restoring spawning habitat through gravel augmentation and channel narrowing to increase sediment transport is unlikely to substantially increase adult recruitment, because the loss of eggs and fry from degraded habitats and redd superimposition has been inconsequential to the production of smolts in the Tuolumne River. This is because many more juveniles have been produced in spite of the degraded spawning habitat, than survived to a smolt-size under the FSA flows schedules.
3. It appears that restoration of captured mine pits to reduce abundance of black bass is unlikely to substantially increase adult recruitment in the Stanislaus and Tuolumne Rivers.
4. To stop the decline and help recover the Tuolumne River salmon and rainbow trout populations, FERC should require the licensee’s to implement two things:
   a. A revised flow schedule is needed substantially improve the production of adult fall-run Chinook salmon, and protect rainbow trout, in the Tuolumne River, and provide the basis for testing flow related hypotheses; and
   b. A rigorous research program aimed at determining refining how specific environmental factors are limiting the production of adult salmon in the Tuolumne River and to provide basic population information on rainbow trout.
5. It appears that Delta Exports, Ocean Productivity, and Ocean Harvest have had little effect on salmon recruitment compared to the importance of winter and spring streamflows.
6. It appears that management, and restoration, should focus on the magnitude and duration of instream flows during both winter and spring as the primary means of achieving adult salmon production targets.

7. As salmon smolts migrate through Tuolumne River, thence the South Delta, primarily from April 1 through mid-June, their survival is highly dependent on spring flow.

8. Salmon need suitable physical habitat for spawning and rearing without stressors from exotic predators and entrainment into unscreened diversions to successfully complete their life cycle and meet adult escapement abundance goals. However, spring flows are the primary factor that limits juvenile production and adult recruitment in the lower Tuolumne River, not degraded spawning habitat and captured gravel pits. The degraded spawning habitat in the lower Tuolumne River produces more juveniles than can survive to a smolt-size, and so, improving spawning habitat or restoring fluvial geomorphic processes to naturally improve the quality of spawning habitats will not substantially increase the production of smolts or adult recruitment.

9. For habitat restoration to be effective, the Agencies recommend management focus should be upon protecting and enhancing habitats that improve food availability, help provide suitable water temperatures, provide instream woody debris to promote channel complexity, and reduce predation assuming that studies verify that predation is a substantial stressor. Effective restoration designs should include the following objectives:
    a. Floodplain habitats should be restored to flood at a natural frequency (i.e., an average of every 1.5 years);
    b. Floodplain soils should be restored to enhance riparian growth, which may be the primary basis of the aquatic food chain;
    c. Mature woody vegetation should be preserved and enhanced;
    d. Spring flows should be ramped down at a rate that promotes the establishment of riparian seedlings; and
    e. Restore streambeds in the dredged and incised channels between La Grange and the Roberts Ferry Bridge that are currently used by few if any salmonids. Water temperatures are most likely to be suitable in this reach due to the proximity of the reservoir.

10. The Agencies recommend additional research will be needed to determine whether physical habitat restoration can be designed to work synergistically with an improved flow schedule to substantially increase smolt production and survival, and eventual adult return. Here are four issues that should be addressed:
    a. Is food availability a primary limiting factor for smolt production, and if so, can food availability be substantially increased by increasing the area and productivity of annually inundated floodplain habitat?
    b. Can the productivity of inundated floodplains be increased by protecting and increasing the abundance of mature woody vegetation and by augmenting the floodplain's surface with soil?
    c. Is water quality a primary determinant of smolt production and survival, and if so, can water quality be substantially improved by restoring riparian vegetation and reducing erosion in the watershed?
    d. Is predation on juveniles a primary determinant of smolt production and survival, and if so, can predation be substantially reduced by restoring degraded habitat that supports large numbers of predators?

11. One year of unsuitable over-summering water temperatures would severely impact two juvenile steelhead production cohorts and thereby constrain two future cohorts by eliminating a majority of the spawners.
12. A source of wild, or hatchery reared, juvenile salmon and steelhead will be needed for several of the monitoring studies identified herein.
13. The Agencies believe an improved, and expanded, rainbow trout monitoring program is needed to effectively manage the Tuolumne River rainbow trout population.

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Appendix A

Preliminary Recommended Tuolumne River Fall-run Chinook Salmon and Rainbow Trout Studies

Preliminary Tuolumne River Proposed Salmonid Studies (08-15-06)--Page 1													
Fish Species	**Task**	**Estimate Provided By**	**Current Funding Source**	**Year (Assumes 2007 Start Year)**									
				1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Fall-run Chinook Salmon	Chinook salmon escapement and redd surveys	CDFG	ERP	$75,000	$77,250	$79,568	$81,955	$84,413	$86,946	$89,554	$92,241	$95,008	$97,858
	Otolith and/or Scale Age analysis for Chinook salmon	"ball-park estimates"	ERP	$100,000	$15,000	$15,450	$15,914	$16,391	$16,883	$17,389	$17,911	$18,448	$19,002
	Rotary Screw Trap: Spring Upper and Lower Sites	Cramer Fish Sciences	ERP	$350,000	$360,500	$371,315	$382,454	$393,928	$405,746	$417,918	$430,456	$443,370	$456,671
	CWT smolt survival studies during non-low flows	CDFG	TBD	$50,000		$50,000		$50,000		$50,000		$50,000	
	Smolt Spring Migration Patterns (sonic tags)	NRS - Dave Vogel	ERP	$225,000	$175,000	$175,000	$175,000		$175,000				
	Juvenile Fish Histology, Physiology, and Disease Study	USFWS	ERP	$75,000	$77,250	$79,568	$81,955	$84,413	$86,946	$89,554	$92,241	$95,008	$97,858
	Predation Rate--Electrofishing Study)	"ball-park estimates"	ERP	$120,000	$123,600	$127,308							
	Predation Rate--Angling Study	"ball-park estimates"	ERP	$60,000	$61,800	$63,654							
	Potential Phase II Predator Abundance Study	"ball-park estimates"	TBD						$500,000				

Estimated Costs by year for the Tuolumne River Salmonid Research Program over a 10 year period. Costs assume 3% annual inflation rate.

Shaded years = years currently funded

Preliminary Tuolumne River Proposed Salmonid Studies (08-15-06)--Page 2													
Fish Species	**Task**	**Estimate Provided By**	**Current Funding Source**	**Year (Assumes 2007 Start Year)**									
				1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Fall-run Chinook Salmon	Water Quality Contaminant Study	UC Berkeley	TBD	$235,000	$185,000		$185,000						
	Potential juvenile food availability studies	TBD	TBD				TBD	TBD	TBD				
	Entrainment studies at unscreened diversions	TBD	TBD	TBD	TBD								
	Fall Pulse Flow Study on Egg Viability.	"ball-park estimates"	TBD	$37,500									
	Pre-spawn mortality Study	"ball-park estimates"	ERP	$15,000	$15,000	$15,000	$15,000						
	Pilot Microchemical and Microstructural Otolith Study	Lawrence Livermore National Laboratory	TBD	$100,000									
	Intensive Redd Use Survey.	"ball-park estimates"	TBD	$30,000		$30,900		$31,827		$32,782			
	Water Temperature Monitoring	"ball-park estimates"	ERP/TID	$25,000	$25,750	$26,523	$27,318	$28,138	$28,982	$29,851	$30,747	$31,669	$32,619

Estimated Costs by year for the Tuolumne River Salmonid Research Program over a 10 year period. Costs assume 3% annual inflation rate.

Shaded years = years currently funded

Preliminary Tuolumne River Proposed Salmonid Studies (08-15-06)--Page 3													
				Year (Assumes 2007 Start Year)									
Fish Species	**Task**	**Estimate Provided By**	**Current Funding Source**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Fall-run Chinook Salmon	Water Temperature Modeling-Thermal Response (e.g. HEC5Q)	ERP	ERP	$250,000	$250,000								
	Water Temperature Modeling-Juvenile Production (e.g. SALMOD or ORCM)	"ball-park estimates"	TBD		$125,000	$125,000							
	Egg survival to emergence studies in restoration gravels	"ball-park estimates"	TBD	$50,000	$51,500	$53,045		$54,636		$56,275			
	Riparian Vegetation Recruitment Surveys	"ball-park estimates"	TBD	TBD									

Estimated Costs by year for the Tuolumne River Salmonid Research Program over a 10 year period. Costs assume 3% annual inflation rate.

Shaded years = years currently funded

Preliminary Tuolumne River Proposed Salmonid Studies (08-15-06)--Page 4													
Fish Species	**Task**	**Estimate Provided By**	**Current Funding Source**	**Year (Assumes 2007 Start Year)**									
				1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Rainbow Trout	Otolith and Scale Study	CDFG	TBD	$55,000	$56,650	$58,350	$60,100	$61,903	$63,760	$65,673	$67,643	$69,672	$71,763
	Restored Site Snorkel of Videography Surveys	"ball-park estimates"	TBD	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000
	Electro-fishing Adult Mark-Recapture Study	"ball-park estimates"	TBD	$130,000	$133,900	$137,917	$142,055	$146,316	$150,706	$155,227	$159,884	$164,680	$169,621
	Adult Abundance--Snorkeling Survey	"ball-park estimates"	TBD	$52,000	$53,560	$55,167	$56,822	$58,526	$60,282	$62,091	$63,953	$65,872	$67,848
	Juvenile Abundance Snorkel Surveys	"ball-park estimates"	TBD	$40,000	$41,200	$42,436	$43,709	$45,020	$46,371	$47,762	$49,195	$50,671	$52,191
	Rotary Screw Trap Sampling	see Salmon	n/a	Covered Under Fall-run Chinook Salmon									
	Juvenile Gill-ATPase Study	"ball-park estimates"	TBD	$78,000	$80,340	$82,750	$85,233	$87,790	$90,423	$93,136	$95,930	$98,808	$101,772
	IFIM Study	"ball-park estimates"	TBD			$250,000	$250,000	$250,000					

Estimated Costs by year for the Tuolumne River Salmonid Research Program over a 10 year period. Costs assume 3% annual inflation rate.

Shaded years = years currently funded

Preliminary Tuolumne River Proposed Salmonid Studies (08-15-06)--Page 5													
Fish Species	**Task**	**Estimate Provided By**	**Current Funding Source**	**Year (Assumes 2007 Start Year)**									
				1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Rainbow Trout	Radio Telemetry/Sonic Tag Study	"ball-park estimates"	TBD				$225,000	$175,000	$175,000				
	Creel/Poaching Survey	"ball-park estimates"	TBD	$50,000	$51,500	$53,045							
	Water Temperature Monitoring	"ball-park estimates"	ERP/TID	$25,000	$25,750	$26,523	$27,318	$28,138	$28,982	$29,851	$30,747	$31,669	$32,619
	Water Temperature Modeling-Thermal Response (e.g. HEC5Q)	ERP	ERP	$250,000	$250,000								
	Water Temperature Modeling-Juvenile Production (e.g. SALMOD or ORCM)	"ball-park estimates"	TBD		$125,000	$125,000							
	Adult Redd Survey	"ball-park estimates"	TBD	$80,000	$82,400	$84,872	$87,418	$90,041	$92,742	$95,524	$98,390	$101,342	$104,382
	Limiting Factors Analysis	"ball-park estimates"	TBD				$75,000	$75,000					

Estimated Costs by year for the Tuolumne River Salmonid Research Program over a 10 year period. Costs assume 3% annual inflation rate.

Shaded years = years currently funded